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THE REGULATORY AND ECONOMIC IMPACT OF MANDATORY REQUIREMENTS FOR SHOULDER HARNESSES IN SMALL COMMERCIAL AEROPLANES AND COMMERCIAL HELICOPTERS

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Un sommaire en français de ce rapport est inclus avant la table des matières.

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16. Abstract

A study was undertaken to assess the regulatory and economic impact of mandatory requirements for shoulder harnesses in flight crew seats of all small commercial aircraft regardless of their date of manufacture, and to investigate the general availability of low cost harness kits. Regulatory requirements for shoulder harnesses in Canada were found to be less advanced than in the U.S. and Australia. Analysis of Canadian accident data indicated that shoulder harnesses are very effective at preventing fatalities and injuries in both small aeroplane and helicopter accidents. Retrofit kits are available for about 85% of the fleet at an average cost (for the front seats) of $2160 for aeroplanes and $3750 for helicopters. A benefit cost ratio of 20 was found for retrofitting the current fleet. It is recommended that front seats of all small commercial aircraft be fitted with shoulder harnesses by a time to be set in consultation with commercial operators, and that use of the shoulder harnesses be mandatory during take-off and landing.

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16. Résumé

L'objectif de la recherche a été d'évaluer l'impact réglementaire et économique de la décision de rendre obligatoire l'installation de harnais de retenue pour l'équipage de conduite de tous les petits avions commerciaux, sans égard à la date de construction de ceux-ci, et de vérifier dans quelle mesure il existe sur le marché des harnais bon marché. La recherche a montré que le Canada est à la traîne des États-Unis et de l'Australie pour ce qui est de la réglementation en matière de harnais de retenue. L'analyse des statistiques canadiennes sur les accidents montre que le port d'un harnais réduit très effectivement le nombre de tués et la gravité des blessures dans les accidents impliquant des petits avions ou des hélicoptères. Près de 85 p. 100 de ceux-ci peuvent être rééquipés d'un harnais aux deux sièges avant à un coût moyen de 2 160 ou de 3 750 dollars, respectivement. Le rapport des avantages d'un rééquipement au coût à consentir est présentement de 20. Il est recommandé que les sièges avant de tous les petits avions engagés dans des opérations commerciales soient équipés d'un harnais de retenue dans un délai à être fixé de concert avec les exploitants, et que le port du harnais soit rendu obligatoire durant les décollages et les atterrissages.

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SUMMARY

1. INTRODUCTION

Transport Canada determined that a study should be undertaken to examine all reasonable means for implementing the mandatory installation of shoulder harnesses in flight crew seats of all small commercial aircraft regardless of their date of manufacture.

2. OBJECTIVE

The objective was to assess the regulatory and economic impact of mandatory requirements for shoulder harnesses in flight crew seats of all small commercial aircraft regardless of their date of manufacture and to investigate the general availability of low-cost harness kits.

3. U.S. AND AUSTRALIAN REGULATIONS

A review of U.S. and Australian regulations for small aircraft was undertaken because the U.S. supplies most of the small commercial aircraft and because Australian safety regulation often provides international leadership. The results were rewarding and clearly indicate that Canada has less shoulder harness regulation than both countries. In fact there is no regulation in Canada which requires that shoulder harness be fastened during take-off and landing.

4. ANALYSIS OF ACCIDENT DATA

It was decided that an assessment of accident data would provide the basis for the estimation of injury and fatality rates with and without shoulder harnesses. There are two methods of analyzing accident data to assess the effectiveness of shoulder harnesses:

- compare rates of injury of occupants with and without shoulder harnesses,
- select a sample of accidents where no shoulder harness was worn and investigate the survivability had a shoulder harness been worn based upon the types of injuries, deceleration G forces, impact angle and intrusion of airframe into the pilot seat area.

This study used both methods and determined that the classification of accidents as survivable and non-survivable is not independent of shoulder harness usage, so both types of accidents were used in the study.

A U.S. Federal Aviation Administration (FAA) study found that shoulder harness installation does not reduce the chance of fatal injury, but marginally reduces the rate of serious injury. U.S. National Transportation Safety Board (NTSB) indicates 75% of fatalities would be prevented in survivable accidents and injuries reduced by 79%.

In Canada, the incidence of fatal accidents among pilots (of fixed wing aircraft) who wore shoulder harnesses was found to be half that of those who did not. The reduction in the serious injury rate is similar. The data for rotary wing is similar but indicates shoulder harness is more effective at reducing fatalities for such aircraft than it is for fixed wing aircraft, probably due to the lower forward speeds at impact. However, the reduction of injuries is less effective than it is for fixed wing.

The study used the Canadian Aviation Safety Board (CASB) observed data as well as the NTSB published methodology to estimate the injury reduction possibilities in 300 pilot injury/fatality accidents if shoulder harnesses had been worn.

The following conclusions can be reached from the accident analysis.

- Shoulder harnesses are very effective at reducing the severity of injuries to pilots in both small aeroplane and helicopter accidents. The effectiveness of shoulder harness is about the same for both types of aircraft.

- Approximately 38 fatalities and 64 serious injuries could have been prevented had all pilots of small commercial aeroplanes and commercial helicopters worn shoulder harnesses since 1976. A further 4 fatalities and 7 serious injuries could also have been prevented to co-pilots by shoulder harness usage.

- The effectiveness of compulsory installation of shoulder harnesses would be significantly reduced if wearing of shoulder harnesses was not also made compulsory.

- Pilots who do not wear available shoulder harnesses are involved in more serious accidents than pilots who wear available shoulder harnesses.

5. COST OF SHOULDER HARNESS RETROFIT KITS

An extensive survey of the aircraft manufacturers, distributors, suppliers, operators, and overhaul shop was undertaken to acquire cost data to retrofit aircraft not equipped with shoulder harnesses in the front seats.

The data provides installation costs for about 85% of the small commercial aeroplanes and helicopters. The costs range from $264 to $4,766 for aeroplanes with an average of $2,163 and from $1,883 to $6,974 for helicopters with an average of $3,750. It was not possible to estimate the lead time required for the installation of shoulder harnesses in the front seats of all aircraft not now equipped. As a consequence it is recommended that this should be determined after full consultation with the commercial aircraft operators.

6. COST-BENEFIT ANALYSIS

Cost-benefit analysis was used to determine if retrofitting shoulder harnesses in commercial helicopters and small commercial aeroplanes can be justified.

The methodology used included a means to estimate how many aircraft are not now fitted with shoulder harnesses in the front seats and to calculate the cost of retrofitting each aircraft. Next, the net present value of injuries and fatalities prevented by the installation and use of shoulder harnesses over the aircraft's life span was estimated allowing for lower utilization of old aircraft. This was then used to calculate the cost-benefit for each aircraft and to arrive at the overall cost-benefit ratio resulting from the retrofit of all aircraft.

Benefits exceeded costs by a factor of at least 5 for a wide range of conditions tested using a sensitivity analysis and a cost-benefit ratio of 23 for aeroplanes and 13 for helicopters was found for medium/most likely conditions. The retrofitting of shoulder harnesses in old aircraft is cost effective provided they will be flown for several more years at typical utilization rates.

7. CONCLUSIONS

Currently shoulder harnesses are installed in approximately half of the helicopters and small commercial aeroplanes, i.e., in about 500 helicopters and 2000 small commercial aircraft.

The average shoulder harness retrofit costs are $2160 for small aeroplanes and $3750 for helicopters for both front seats.

Retrofitting of shoulder harnesses in the front seats of helicopters and small commercial aeroplanes will prevent approximately 110 fatalities and 50 serious injuries over their life span.

The estimation of lead time to retrofit all aircraft front seats not now equipped with shoulder harnesses is impracticable because of the lack of certainty on the availability of kits, parts, and the condition of the aircraft seats, support structure and lap-belts.

It is concluded that the cost-benefit ratio of 20 warrants the retrofitting of all commercial aeroplanes under 12,500 lbs and all commercial helicopters.

8. RECOMMENDATIONS

It is recommended that all commercial aeroplanes under 12,500 lbs and all commercial helicopters be retrofitted with shoulder harnesses in the front seats where such equipment is not now fitted.

It is recommended that the effective date be established after consultation with the commercial operators, or within five years if no agreement is reached.

It is recommended that wearing shoulder harness be made mandatory for take-off and landing for the front-seat occupants.

It is recommended that inertia reels not be required provided that the pilot can reach essential controls and equipment with the shoulder harness fastened.

SOMMAIRE

Introduction

Transports Canada considère qu'une étude devrait être entreprise sur toutes les mesures raisonnables pouvant être prises pour faire équiper obligatoirement les sièges de l'équipage de conduite de tous les petits aéronefs commerciaux d'un harnais de retenue, sans égard à la date de construction de ces appareils.

Objectif

L'objectif de la recherche a été d'évaluer l'impact réglementaire et économique de l'installation obligatoire de harnais de retenue pour l'équipage de conduite de tous les petits aéronefs commerciaux, sans égard à la date de construction de ceux-ci, et de vérifier dans quelle mesure il existe sur le marché des harnais bon marché.

Réglementation des États-Unis et de l'Australie

La réglementation des États-Unis et de l'Australie concernant les petits aéronefs a été examinée étant donné que les États-Unis construisent la plupart des petits aéronefs commerciaux, et que l'Australie se présente souvent comme chef de file en matière de sécurité. Les résultats fructueux de la recherche montrent clairement que le Canada est à la traîne de ces deux pays pour ce qui est de la réglementation en matière de harnais de retenue, d'autant qu'aucune réglementation canadienne ne prescrit que le harnais doit être bouclé durant les décollages et les atterrissages.

Accidentologie

Il a été déterminé que l'analyse des données sur les accidents permettrait d'estimer le nombre de tués et de blessés, avec et sans harnais. Deux méthodes sont utilisables :

- comparer le nombre de blessés avec harnais au nombre sans harnais;

- sélectionner un certain nombre d'accidents, où les occupants ne portaient pas de harnais, et étudier dans quelle mesure le port de tels dispositifs aurait pu accroître les chances de survie, compte tenu de la nature des blessures, des forces de décélération en jeu, de l'angle d'impact et de la pénétration d'éléments de cellule dans l'espace occupé par l'équipage de conduite.

Se servant de ces deux méthodes, les chercheurs ont pu déterminer que la distinction entre accidents offrant des chances de survie et ceux n'en offrant aucune n'est pas indépendante de l'emploi d'un harnais, et que ces deux types d'accident devaient donc être pris en considération.

Une étude de la Federal Aviation Administration des États-Unis montre que le port d'un harnais ne réduit pas les risques d'un accident mortel, mais seulement ceux de lésions graves, et encore légèrement. Une autre étude américaine, cette fois par le National Transportation Safety Board, montre que, dans les accidents avec survivants, le nombre de tués et de blessés pourrait être réduit de 75 et 79 p. 100, respectivement.

Au Canada, le nombre de tués parmi les pilotes d'aéronefs à voilure fixe ayant porté un harnais s'est révélé être la moitié de ceux qui n'en portaient pas. Le nombre de blessés graves était réduit dans à peu près la même proportion. Bien que semblables aux précédentes, les statistiques relatives aux aéronefs à voilure tournante montrent que le port du harnais réduit les risques de décès dans une plus grande proportion que dans le cas des aéronefs à voilure fixe, étant donné peut-être la vitesse moins élevée des premiers, mais qu'il contribue moins bien à protéger contre les blessures.

La recherche s'est fondée tant sur les données fournies par le Bureau canadien de la sécurité aérienne que sur la méthodologie publiée par le National Transportation Safety Board dans son approche pour apprécier la mesure dans laquelle le port du harnais aurait pu réduire la gravité des blessures, et ce dans 300 cas de pilotes tués ou blessés.

La présente recherche a abouti aux conclusions suivantes :

- Le port d'un harnais réduit très effectivement la gravité des blessures subies par le pilote d'un petit avion ou d'un hélicoptère en cas d'accident, le degré d'efficacité étant à peu près égal dans les deux cas.

- Si, depuis 1976, tous les pilotes des petits avions et hélicoptères engagés dans des opérations commerciales et accidentés avaient porté le harnais, quelque 38 vies auraient pu être sauvées et 64 cas de blessures graves évités. Dans le cas des copilotes, ces chiffres auraient pu être accrus de 4 et de 7, respectivement.

- Il ne suffit pas de prescrire l'installation des harnais, il faut également en rendre le port obligatoire.

- Les accidents où les pilotes n'avaient pas bouclé leur harnais sont plus graves que ceux où les pilotes l'avaient bouclé.

Coût du harnais en rééquipement

Une vaste enquête a été faite auprès de tous les milieux aéronautiques concernés : avionneries, distributeurs, fournisseurs, exploitants et ateliers d'entretien, dans le but de déterminer ce que pourrait coûter l'installation en rééquipement de harnais de retenue sur les sièges avant.

Les données qui ont pu être recueillies concernant 85 p. 100 environ des petits avions et des hélicoptères engagés dans des opérations commerciales, montrent que le coût d'installation d'un harnais se situerait entre 264 et 4 766 dollars (moyenne 2 163 dollars) pour les avions, et entre 1 883 et 6 974 dollars (moyenne 3 750 dollars) pour les hélicoptères. Le temps que nécessiterait le rééquipement de tous les aéronefs - sièges avant seulement - n'a pas pu être estimé. Il est donc recommandé que cet aspect de la question soit approfondi avec les exploitants eux-mêmes.

Analyse avantages-coût

La technique de l'analyse avantages-coût a permis de montrer dans quelle mesure l'installation de harnais en rééquipement dans les petits avions et les hélicoptères engagés dans des opérations commerciales serait justifiée.

On a commencé par calculer combien d'aéronefs ne sont pas encore équipés de harnais aux sièges avant et combien leur rééquipement coûterait. Ensuite, on a calculé la valeur actuelle nette des morts et des blessures que le port du harnais permet de prévenir durant le cycle de vie de l'aéronef, compte tenu du fait que la cadence d'exploitation d'un aéronef diminue avec l'âge de ce dernier. Enfin, le rapport avantages-coût pour chaque aéronef a été calculé, d'où a été tiré le rapport avantages-coût global, c'est-à-dire de tous les harnais devant être installés en rééquipement.

L'analyse a montré que le rapport des avantages au coût est d'au moins 5 pour une vaste gamme de conditions contrôlées et soumises à une analyse de la sensibilité, et qu'il atteint 23 et 13 pour les petits avions et les hélicoptères, respectivement, pour les conditions d'exploitation les plus répandues, voire les plus probables. Dans le cas d'aéronefs qui ont vieilli, leur rééquipement est rentable à condition qu'ils continuent d'être exploités pendant quelques années encore, à une cadence normale.

Conclusions

La moitié environ des hélicoptères et des petits avions engagés dans des opérations commerciales sont actuellement équipés de harnais, c'est-à-dire quelque 500 hélicoptères et 2 000 petits avions.

Le rééquipement des sièges avant coûte en moyenne 2 160 dollars pour les petits avions et 3 750 pour les hélicoptères.

En revanche, cela permettra de sauver près de 110 vies et d'éviter des blessures graves à 50 autres personnes durant le cycle de vie des aéronefs.

Le temps que nécessiterait le rééquipement des sièges avant s'avère difficile à établir étant donné les incertitudes entourant la disponibilité des harnais et des pièces de rechange sur le marché ainsi que l'état des sièges, de leur assise et des ceintures abdominales.

La recherche montre qu'un rapport avantages-coût de 20 justifie amplement le rééquipement de tous les avions pesant moins de 12 500 lb, ainsi que de tous les hélicoptères, engagés dans des opérations commerciales.

Recommandations

Il est recommandé que des harnais soient installés en rééquipement sur les sièges avant dans tous les avions pesant moins de 12 500 lb et dans tous les hélicoptères engagés dans des opérations commerciales.

Il est recommandé que la date limite d'installation soit fixée de concert avec les exploitants ou, faute d'un accord réciproque, dans un délai de cinq ans.

Il est recommandé que le port du harnais soit rendu obligatoire pour les occupants des deux sièges avant, durant les décollages et les atterrissages.

Il est recommandé de ne pas exiger des enrouleurs à inertie lorsque le pilote peut atteindre les commandes et les équipements essentiels après avoir bouclé le harnais.

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1. INTRODUCTION/BACKGROUND

Canadian interest in small aircraft crashworthiness was re-kindled in the 1980s by the 1980-1983 Commission of Inquiry into Aviation Safety, and the the desire to contribute to U.S./Canada aeronautical research and development. As well, aircraft accident analyses have pointed to the probability that many of the fatalities and serious injuries experienced could have been prevented through improved crashworthiness including the mandatory use of shoulder harnesses.

As a consequence, Transport Canada commissioned a study on Small Aircraft Crashworthiness which was carried out by SYPHER:MUELLER International Inc. in 1985. The final report, TP 8655E dated July 1987, reviewed past accident investigations, regulatory developments and crashworthiness research activities for small aeroplanes in Canada and the United States.

The recommendations of TP 8655E included the need for a Canadian general aviation crashworthiness program, including the retrofit and post-crash survival of small aeroplanes and the associated cost-benefit analyses, and a review of the FAA contemporary related actions.

Transport Canada held a Seminar on March 9, 1988 on Small Aircraft Crashworthiness Research and Development to review the areas where Canada could make a meaningful contribution. Once again the role of the shoulder harness in preventing deaths and serious injury was prominent in the discussions. As a consequence of the seminar, Transport Canada elected to organize a Small Aircraft Crashworthiness Research and Development Committee in 1988 to coordinate and advise Transport Canada on the conduct of research and development initiatives for the improvement of the crashworthiness of small aeroplanes in Canada. In particular it determined among its objectives aspects of small aeroplane crashworthiness.

The Committee established a plan in 1989 which included the decision to study shoulder harnesses for small aircraft which would respond to a recommendation of the Canadian Aviation Safety Board (CASB) to require shoulder harnesses in the front seats of small commercial aircraft, and which is in keeping with the overall Transport Canada examination of small aircraft crashworthiness.

The CASB recommendation stated that Transport Canada "make mandatory the installation of shoulder harnesses where practicable in flight crew seats of all small commercial aircraft regardless of their date of manufacture". Transport Canada's response was that a study would be undertaken to determine all reasonable means for including all small commercial aircraft in the planned requirements. It was determined from discussion with the CASB that aircraft was intended to include fixed and rotary wing.

2. OBJECTIVE

The objective of the study is to assess the regulatory and economic impact of mandatory requirements for shoulder harnesses in flight crew seats of all small commercial aeroplanes and commercial helicopters regardless of their date of manufacture, and to investigate the general availability of low-cost shoulder harness kits.

3. METHODOLOGY

3.1 Australia and USA Experience

The report TP 8655E contains a comprehensive review of the U.S. FAA studies and regulation pertaining to the utilization of shoulder harness in small aircraft, and this work was the obvious baseline for a Canadian approach to the study of shoulder harness regulations. Specifically, FAR 23, 27, 29, 91, and 135 were examined for relevant clauses, plus an FAA Draft Advisory Circular AC21 prepared by FAA HQ ANS - 120 undated, and an FAA consultant study by Pailen - Johnson Associates Inc. August 20, 1986 entitled "Retrofit of Shoulder Harnesses is General Aviation Aircraft".

A decision was also made to review the Australian regulations for shoulder harnesses because of contacts between Transport Canada Airworthiness Staff and the Australian Airworthiness Authority which suggested that the Australian experience would be helpful.

A review of the Transport Canada regulations was undertaken and discussions were held with the CASB to verify if it intended rotary wing aircraft to be included in its recommendation, and also to understand its intention by the conditionality statement "where practicable".

3.2 Rotary Wing Aircraft

Helicopter Airworthiness Design Criteria are FAR 27 for takeoff weights up to 6,000 lbs, and FAR 29 for design takeoff weights under 20,000 lbs and 10 or more passengers; all takeoff weights 20,000 lbs and greater. Because these weight groups do not match the fixed wing small aircraft definition it was decided the small rotary wing aircraft grouping would be too restrictive so the study includes all commercial rotary wing aircraft.

All rotary wing aircraft (commercial, private and state) were used in determining the effectiveness of shoulder harness at preventing death and injury to increase the sample size and accuracy of estimates. Three quarters of all helicopters are registered as commercial.

3.3 Canadian Accident Data Analysis

The CASB Accident data was reviewed to estimate the number of lives lost and the number of serious injuries incurred in accidents with and without flight crew harnesses since 1977. The basis for the analyses was survivable and unsurvivable accidents involving small commercial aeroplanes and commercial helicopters.

A methodology was developed to estimate pilot injury rates with and without shoulder harness usage and the injury reduction due to shoulder harnesses. The methodology is explained in the accident analysis section.

3.4 Retrofit Costs and Impact

Retrofit costs for each type of aircraft were obtained from the aircraft manufacturer and equipment manufacturers. The costs for each aircraft type were used in the cost-benefit analysis. However, the costs for 57 types of aircraft (about 15% of registered small commercial aeroplanes and helicopters) could not be determined, so it was necessary to estimate costs from available data of a range of likely costs. The methodology is developed in Section 8 Cost-Benefit Analysis.

The impact of shoulder harness installation was determined using the aircraft register and estimates of the probability of an accident given the age of the aircraft, the injury reduction rates due to shoulder harness installation and usage, and a range of dollar values for the prevention of death and injury. A cost-benefit analysis was done and comparisons made with U.S. data. A full description methodology is given in Section 9.

4. REGULATORY REQUIREMENT DEVELOPMENT - AUSTRALIA

(a) In 1967 the Australian Government issued an Airworthiness Advisory Circular (AAC 15-3) stating that due to accident data, all new aircraft introduced onto the Australian Civil Register after July 1967 will be required to have approved safety harnesses, or combination seat belt and sash, fitted for the pilots and any other occupant of front seats which are basically crew seats. It further stated that this requirement would be stated in Air Navigation Order (ANO) Part 101 and that it would apply to all private, aerial work and RPT aircraft.

The ANO provided relief for aircraft weighing less than 12,500 lb. and imported in the period 1 July 1967 to 1 January 1970 if it could be shown that the aircraft design status would make it unreasonable to insist on compliance.

Within this AAC and implied in all others is that a safety harness includes some form of shoulder restraint as well as a seat belt.

(b) AAC #54-1 issued July 1971 advised that ANO Section 101.22 now imposes USA FAR 23.785 at Amendment 7 effective 14 October 1969, on all new aircraft types coming onto the Australian Register but the ANO did not make this design requirement retroactive to older aircraft already in service even though they may still be in production. However the AAC did go on to state that it was the Departments intention to issue a series of ANO's that would require all aircraft weighing 12,500 lb. or less to be fitted with an approved upper body restraint system for compliance within two years.

This resulted in Airworthiness Directives (AD's) being issued under ANO Part 105 on October 1971 causing all Beechcraft 33 & 35 - 33,55, 58 and 95 - 33 aircraft types to be fitted with safety harnesses in the front seats before 1 September 1972. The issuance of these AD's was predicated on the knowledge by the authorities that approved installation schemes did exist.

(c) AAC 69-1 dated March 1972, provided guidelines for the installation of upper body restraint systems for those aircraft for which no installation schemes existed.

(d) AAC 69-4 dated November 1973 stated that if inertia reels are fitted to the front left seat of the aircraft, an inertia reel would not be required for the right front seat but did not make an inertia reel mandatory. The AAC also listed some of the aircraft types for which inertia reel installations were and were not required. It is assumed that the need for an inertia reel was to meet the need for the crew to reach the essential equipment.

(e) In December 1972, an Airworthiness Directive was issued on Beechcraft models 19,23 & 24 series aircraft requiring front seat safety harness to be installed with inertia reel for the pilot but if the aircraft was used for training purposes then both front seats would require inertia reels.

(f) Effective May 1981, ANO Part 101, Section 101.0, Sub-Section 3.10, requires that each flight crew and cabin crew seat and each cockpit front seat of each aircraft be fitted with a safety harness before issue of a C of A and shall incorporate, where necessary, an inertia reel in order to provide the crew with full and unrestricted movement.

(g) In February 1988, a Airworthiness Directive was issued requiring all aeroplanes of 5700 kg or less, manufactured after December 1986, with nine passenger seats or less to have a safety harness installed for each seat prior to 31 August 1988.

5. REGULATORY REQUIREMENT DEVELOPMENT - UNITED STATES

(a) FAR 91.33 Amendment 139 16 June 1977

Incorporated the requirement - "For small civil airplanes manufactured after 18 July 1978, an approved shoulder harness for each front seat designed to protect the occupant from serious head injury when occupant is subjected to inertia forces specified in FAR 23.561 (b) (2)".

At this time it was not mandatory in FAR 91 to wear the shoulder harness, only the safety belts.

FAR 91 Amendment 139 was incorporated at the same time that FAR 23 Amendment 19 was issued, which incorporated the requirement for front seat harness and also stated that the new requirement would apply to an application for a type certificate after 18 July 1978.

(b) FAR 91.14 Amendment 191 13 November 1985

Incorporated the requirement that safety belts and shoulder harness, if installed, must be used by all persons before take-off or landing of an aircraft.

(c) FAR 91.33 Amendment 191 13 November 1985

Incorporated the requirement - "For normal, utility and acrobatic category airplanes with a seating configuration, excluding pilots seats, of nine or less, manufactured after 12 December 1986, a shoulder harness for:

(i) Each front seat that meet the requirements of FAR 23.785 (g) and (h) in effect on 12 December 1985:

(ii) Each additional seat that meets the requirements of FAR 23.785 (g) in effect on 12 December 1985.

At the same time that FAR 91 Amendment 191 was incorporated, FAR 23 Amendment 32 introduced the same design requirement for each normal, utility and acrobatic airplane manufactured one year after 12 December 1985 and also stated that the new requirement applied to any such foreign manufactured airplane for entry into the U.S.

(d) FAR 135.171

Requires that no person may operate a turbojet aircraft or an aircraft having a passenger seating capacity of 10 or more, excluding pilot's seat, unless it is equipped with a shoulder harness for each flight crew member station; it goes on to say that the crew member must use the shoulder harness for take-off and landing if it is fitted unless the crew member cannot carry out his duty when it is fitted.

It should be noted that neither FAR 91 nor 23, made reference to the commuter category or SFAR 41 type of airplane if it is operated under 12,500 lbs. (an airplane whose weight is less than or equal to 19000 lb. and whose seating capacity can go up to 19).

(e) FAR 27.285 amendment 21, December 6, 1984, 785(g) required a shoulder harness at front seats of rotorcraft new designs.

FAR 27.785 Amendment 25, December 13, 1989 785(b) requires each occupant must be protected form serious head injury by a safety belt plus a shoulder harness that will prevent the head from contacting any injurious object except as provided for in 27.562(c)(5). A shoulder harness (upper torso restraint) in combination with the safety belt, constitutes a torso restraint as described in TSO-C114.

785(c) requires each pilot's combined safety belt and shoulder harness must allow each pilot when seated with safety belt and shoulder harness fastened to perform all functions necessary for flight operations.

Also an NPRM 89-32 Vol. 54 December 89 No. 235 Page 50688 is in process which would make the amendment 25 applicable to all new production.

(f) FAR 29.785 amendment 24, December 6, 1984 785(g) required a shoulder harness at front seats of rotorcraft new designs.

FAR 29.785 Amendment 29, December 13, 1989 requires in (b) and (c) the identical conditions to that of FAR 27.785 and is the subject of the NPRM identified for FAR 27.785.

6. REGULATORY REQUIREMENT - CANADA

Chapter 523 of the Airworthiness Manual requires shoulder harnesses to be fitted to the front seats of aeroplanes. Prior to the promulgation of the Airworthiness Manual in 1986, Canada utilized FAR 23 as a design standard, thus all aeroplanes designed to FAR 23 amendment 19 were required to have shoulder harnesses fitted to the front seats subsequent to July 18, 1978 the effective date of the Amendment 19.

However, the FAA simultaneously with the issue of amendment 19 also issued FAR 91 amendment 139 which as described on page 9 of this report required shoulder harnesses to be fitted to the two front seats of all aeroplanes manufactured after July 18, 1978.

As a consequence it is likely that all U.S. manufactured FAR 23 aeroplanes imported into Canada after July 18, 1978 were equipped with shoulder harnesses for the two front seats, but because Canada has not adapted FAR 91 there is no obligation for a Canadian operator to maintain the shoulder harnesses in front seats unless the aeroplane was designed subsequent to July 18, 1978.

ANO II No. 2 paragraph 6 requires that every person keep his safety belt or safety harness fastened during take-off and landing, but there is no reference to shoulder harness.

7. ACCIDENT ANALYSIS

7.1 Introduction

The effectiveness of shoulder harnesses at reducing pilot injuries in small aircraft accidents can be assessed using actual Canadian accident data. It has not been compulsory to install shoulder harnesses in small aeroplanes to obtain a Canadian airworthy certification, but aeroplanes registered in the U.S. built after July 18, 1978 must have shoulder harnesses installed for all seats (including passenger seats). As U.S. manufacturers built aeroplanes with shoulder harnesses after mid-1978 and Canadian carriers have been encouraged to install and use shoulder harnesses in their small aeroplanes, many small aeroplanes and helicopters in Canada have shoulder harnesses installed.

Commercial, private and state registered helicopters were used in the evaluation of the effectiveness of shoulder harnesses as the number of helicopter accidents is much less than the number of aeroplanes accidents and the largest possible sample size was required to get significant results. The effectiveness of shoulder harnesses would be expected to be similar in accident involving commercial, private and state registered helicopters. Also, as 77% of all helicopters are registered as commercial, use of all helicopters should not invalidate the estimates.

The usage rate of shoulder harnesses is difficult to determine. Over the period 1976 to 1989, the installation and usage rates of shoulder harnesses in small commercial aeroplanes and helicopters involved in accidents are given in Table 7.1. These usage rates were assumed to also apply to aircraft not involved in accidents.

The usage rates in small aeroplanes are much higher than those found in the U.S. where, in 1982, 50% of aeroplanes had shoulder harnesses installed and only 40% of pilots wore shoulder harnesses when they were available (source NTSB [1][1]). At that time use of available shoulder harnesses was

[1] Numbers in brackets designate references listed at the end of the report.

not mandatory, but in 1985 their use was made mandatory. The installation and usage rates are higher in helicopters than in small commercial aeroplanes. In Canada unavailability of shoulder harnesses is the main constraint on shoulder harness usage.

Table 7.1 Shoulder Harness Installation and Usage Rates for Pilots in Small Commercial Aeroplanes and Helicopters Involved in Accidents - 1976 to 1989

Shoulder Harness	Rates and Set of Aircraft	
Installed	53% of aeroplanes	56% of helicopters
Installed and Used	37% of aeroplanes	46% of helicopters
Used	70% of aeroplanes with shoulder harnesses installed	82% of helicopters with shoulder harnesses installed

There are two methods of analyzing accident data to assess the effectiveness of shoulder harnesses. These are described briefly below.

1. Considering all accidents involving the type of aircraft of interest, compare the injury rates for occupants wearing shoulder harnesses to the rates for occupants not wearing shoulder harnesses. This method relies on the assumption that other properties of the aircraft and crew will be similar, on average, for the two groups and that accident investigations are conducted in a consistent manner. A large number of accidents is required to use this method as the severity of injuries is dependent on many other factors apart from shoulder harness usage and these factors vary greatly from accident to accident.

2. Select a sample of accidents and conduct a thorough investigation of the survivability of the crash, considering such things as the types of injuries sustained by the occupants, the deceleration "G" forces, impact angle and intrusion of aircraft frame into the

pilot's seat area. From this information and knowledge of survivable forces from controlled experiments and past experience, the likely degree of injury had a shoulder harness been worn can be estimated.

The first approach was used in a recent study carried out by Pailen Johnston Associates [2] for the FAA. The study compared the injury rates for occupants of aeroplanes built prior to 1978 with those built after 1978 when installation of shoulder harnesses became compulsory. The study was therefore not directly assessing the effectiveness of shoulder harnesses and, as many of the aeroplanes built prior to 1978 had shoulder harnesses installed, it did not even give good estimates of the injury rates with and without shoulder harnesses installed. The study came to the conclusion that shoulder harnesses do not reduce the chance of being fatally injured, but marginally reduce the rate of serious injury.

The NTSB carried out a detailed investigation of 535 survivable accidents involving aeroplanes to determine the possible effect of shoulder harnesses. The study concluded that 75% of fatalities would be prevented in these types of accidents and the number of serious injuries would be reduced by 79%.

The Canadian Aviation Safety Board undertook a preliminary investigation of the influence of shoulder harnesses in aviation safety [7]. This study lead to the recommendation that shoulder harnesses should be installed in the flight crew seats of all small commercial aircraft, regardless of their date of manufacture.

In this study, both the overall accident rates (approach 1 above) and an investigation of accident report summaries (approach 2 above) were used to evaluate shoulder harnesses. Using the latter approach, results of the NTSB accident investigation were used in conjunction with accident summaries from CASB to estimate the likely injuries had a shoulder harness been used. Both approaches made use of the same accident data, but were carried out independently and results compared after the analysis.

7.2 Injury And Fatality Rates

The ASIS database of aircraft accidents in Canada since 1976 was searched to determine the number of helicopter and small commercial aeroplane accidents, the degree of injury to the pilot and the availability and usage of a shoulder harness by the pilot. Accidents are classified by CASB as survivable, partially survivable or non-survivable on the basis of the injuries sustained, impact angle and damage, and the livable area for occupants. As shoulder harnesses would be expected to be of no use in non-survivable accidents, these were initially considered separately. The results based on this search are given below and the detailed results tables are given in Appendix B.

There were 1548 small commercial aeroplane accidents and 613 helicopter accidents on which to base the comparisons. This number of accidents allows estimates of injury rates (given as a percentage) to be estimated within ± 2% for aeroplane accidents and within 3% for helicopter accidents. For example, the non-injury rate in all small aeroplane accidents is 71% with a 95% confidence interval of 69% to 73%.

The installation and usage of shoulder harnesses can be classified in three ways:

- Installed and used
- Installed and not used
- Not installed

A further breakdown of the category, installed and used, into shoulder harness failed or held can be determined from the CASB accident reports. However, as a shoulder harness can still be effective at reducing injuries even when it fails, and as 65% of pilot shoulder harnesses and seat belts are classified as failing in the CASB data, this breakdown was not considered.

Before comparing injury rates for these classifications, the usefulness of data from non-survivable accident is considered.

7.2.1 Survivable and Non-survivable Accidents

In a truly non-survivable accidents, the usage of shoulder harnesses should be unrelated to the injuries as all occupants would be killed irrespective of their usage of shoulder harnesses. Therefore, one would expect the installation and usage rates in non-survivable accidents to be the same as in all accidents. Since the two groups, survivable and non-survivable, are mutually exclusive and exhaustive subsets of the set of all accidents, the installation and usage rates in the two groups should be the same. However, as shown in Table 7.2, non-survivable accidents have a significantly lower shoulder harness usage than survivable accidents.

Table 7.2 Shoulder Harness Installation and Usage Rates in Survivable and Non-survivable Helicopter and Small Commercial Aeroplanes Accidents*

Aircraft Type	Assigned Accident Type	Installed Used	Installed Not Used	Not Installed
Aeroplane	Survivable	38%	16%	46%
	Non-survivable	27%	17%	56%
Helicopter	Survivable	48%	10%	43%
	Non-survivable	26%	14%	60%

* Includes only accidents where an injury occurred. Distributions significantly different at 95% level (based on Chi-square test) for each aircraft type.

Thus, the survivability assessment made by the investigator is not independent of shoulder harness installation and usage. This could be due to one or both of the following:

. Investigators do not take into account fully the effectiveness of shoulder harnesses in accidents where all occupants perish and are more likely to classify an accident as non-survivable when shoulder harnesses are not worn.

- Pilots not wearing shoulder harnesses are more likely to be involved in non-survivable accidents than pilots that wear shoulder harnesses.

It is likely that both contribute to the relationship found between accident survivability and shoulder harness usage.

There is evidence to suggest that many characteristics of pilots such as over confidence, carelessness, irresponsibility, immaturity and showing resistance against authority are related to safety [3]. The decision by a pilot not to wear a shoulder harness could be an indication that he/she is willing to take more risks than pilots that choose to wear them and could also be a sign of over-confidence. The finding that pilots who do not wear shoulder harnesses are more likely to be involved in non-survivable accident is in agreement with previous evidence on pilot characteristics and safety.

As the classification of accidents as survivable or non-survivable is not independent of shoulder harness installation and usage, both types of accidents were used in the subsequent analyses.

7.2.2 Effectiveness of Shoulder Harness

The effectiveness of pilot shoulder harnesses can be gauged by comparing the distribution of fatalities and injuries from accidents where the shoulder harness was and was not used. As shown in Figure 7.1, the percentage of small commercial aeroplanes pilots killed wearing a shoulder harness is half that of pilots not wearing a shoulder harness. Similarly, 25% of pilots were seriously or fatally injured not wearing shoulder harnesses, while only 13% of pilots wearing shoulder harnesses suffered those injuries. The difference in the distribution of injuries with and without shoulder harnesses is statistically significantly at the 99.9% level.

Pilot injury rates in helicopter accidents are shown in Figure 7.2. As with small aeroplane accidents, the fatality rate is significantly less for pilots wearing shoulder harnesses. The accident data indicates that a shoulder harness is more effective at reducing fatalities, but less effective at reducing serious and minor injuries in helicopter accidents compared to small aeroplane accidents.

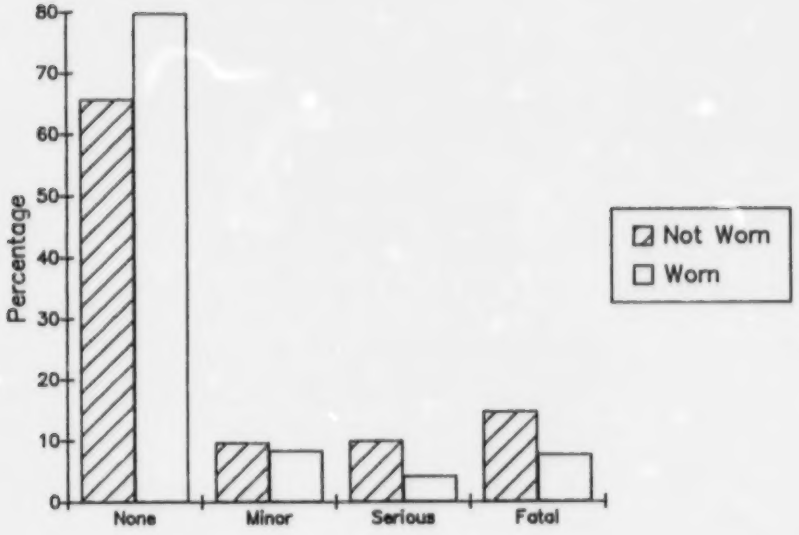

Figure 7.1 Injury Rates for Pilots in Small Commercial Aeroplane Accidents where Shoulder Harness Was and Was Not Worn (1976 - 1989)

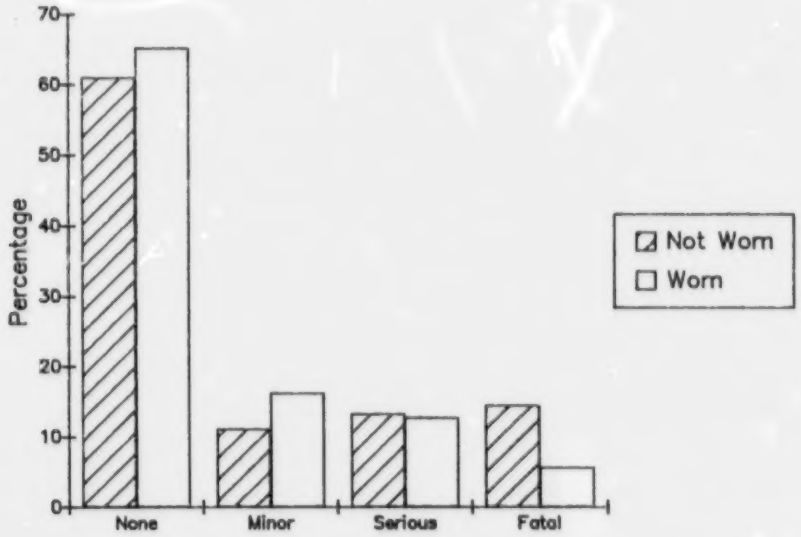

Figure 7.2 Injury Rates for Pilots in Helicopter Accidents where Shoulder Harness Was and Was Not Worn (1976 - 1989)

Aircraft with shoulder harnesses installed tend to be newer aircraft as shoulder harness installation was made compulsory in small aeroplanes in the U.S. in 1978. The characteristics of aircraft may differ between the groups compared in Figures 7.1 and 7.2 and these could have caused the observed differences in injury rates. The pilot injury rates were therefore compared, given a shoulder harness is installed (see Figures 7.3 and 7.4). The effectiveness of shoulder harnesses at reducing injuries is found to be even more evident considering these accidents. Thus, the aircraft characteristics associated with shoulder harness installation appear to have had little effect on the injury rates.

The injury rates with and without shoulder harnesses may be influenced by the relationship between a pilot's willingness to wear a shoulder harness and the accident severity, discussed in Part (i) above. If pilots that use shoulder harnesses when available have less severe accidents than pilots that do not use them, then a similar pattern of injuries to that shown in Figure 7.1 would be expected. Therefore, when evaluating shoulder harness effectiveness by comparing injury rates, the effect of a pilot's willingness to use shoulder harnesses should be removed. This cannot be done easily as in those accidents where a shoulder harness was not installed, the pilot's willingness to wear a shoulder harness could not be determined from the accident reports. A method of removing the effect is outlined in Appendix C. It is shown that shoulder harnesses reduce the fatality rate by about 40% after allowing for the effect of a pilot's willingness to wear a shoulder harness on the accident severity.

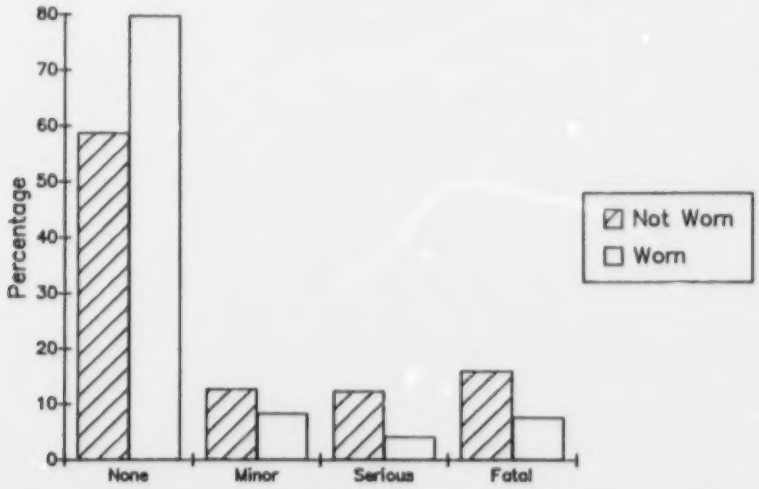

Figure 7.3 Injury Rates for Pilots in Small Commercial Aeroplane Accidents where Shoulder Harness was Installed and Was and Was Not Worn (1976 - 1989)

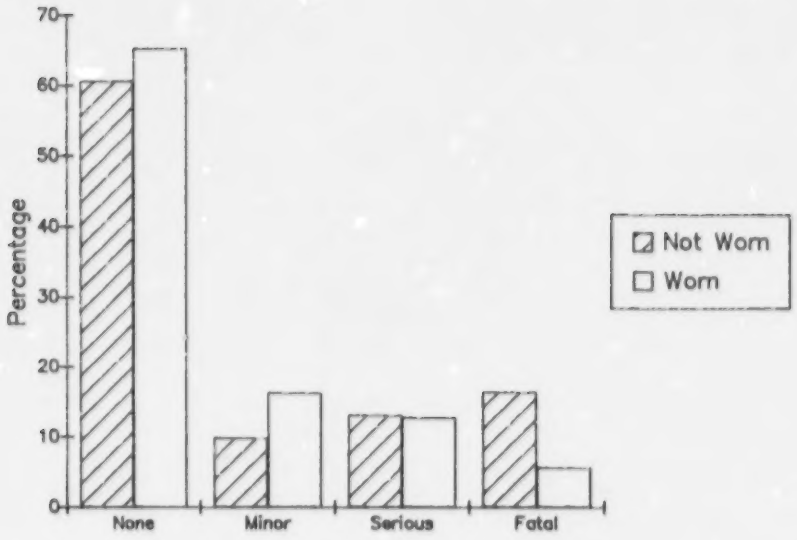

Figure 7.4 Injury Rates for Pilots in Helicopter Accidents where Shoulder Harness was Installed and Was and Was Not Worn (1976 - 1989)

7.2.3 Shoulder Harness Installed and Not Installed

The injury rates to pilots in small aircraft accidents where a shoulder harness was installed or not installed are shown in Figure 7.5 for aeroplanes and Figure 7.6 for helicopters. The differences in the injury rates are far less than when usage of shoulder harnesses was compared, but are significant at the 95% level. The difference is explained largely by the usage rate of shoulder harnesses when they are installed (70% for small commercial aeroplanes and 82% for helicopters). The higher severity of accidents involving pilots who do not wear an available shoulder harness also contributed to the smaller difference.

From these results, it is not surprising that Pailen-Johnston found no significant difference between the fatality rates for aeroplanes with and without shoulder harnesses installed. In the U.S. only about 40% of pilots in accidents were wearing

available shoulder harnesses. This, combined with the different accident severity associated with shoulder harness usage, would greatly reduce the average injury reduction due to shoulder harnesses and make it difficult to detect.

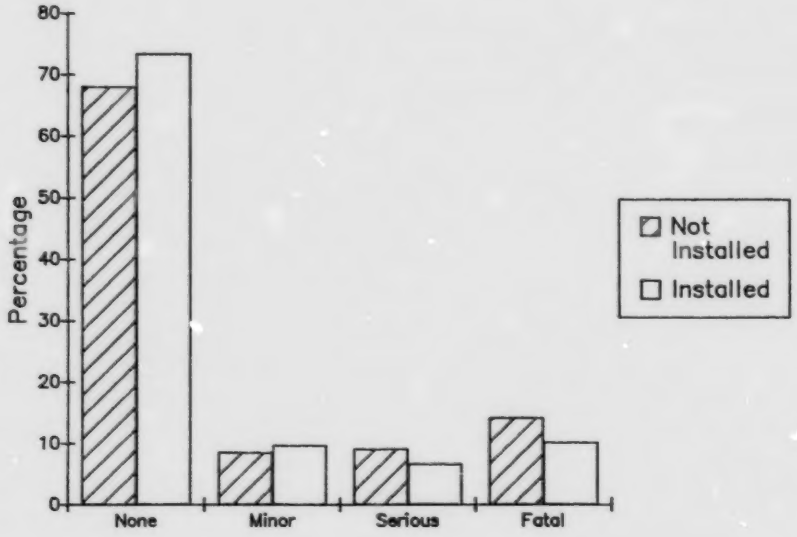

Figure 7.5 Injury Rates for Pilots in Small Commercial Aeroplane Accidents where Shoulder Harness was Installed and was Not Installed (1976 - 1989)

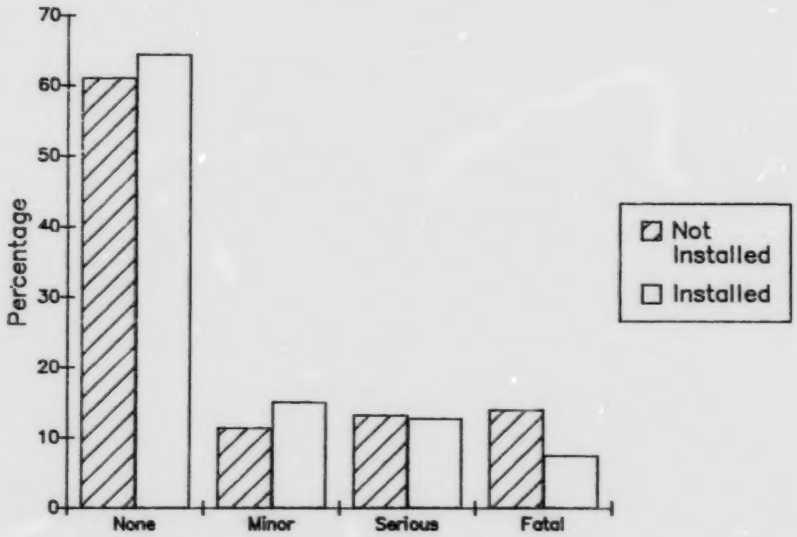

Figure 7.6 Injury Rates for Pilots in Helicopter Accidents where Shoulder Harness was Installed and was Not Installed (1976 - 1989)

The effect of shoulder harnesses will be reduced if shoulder harness installation is made compulsory, but the wearing of available shoulder harnesses is not compulsory. Pilots could be encouraged to voluntarily wear them through education and publicity programs. However, the pilots who, by choice or forgetfulness, do not wear available shoulder harnesses are the pilots who are likely to have more severe accidents. Thus, those pilots needing the shoulder harnesses the most would be the ones least likely to be wearing them.

7.3 Analysis Of Accident Reports

7.3.1 Methodology

Accident summary reports of all survivable and partly survivable accidents involving small commercial aircraft where a pilot or co-pilot was injured and was not wearing a shoulder harness were reviewed to determine the possible injury reduction had a shoulder harness been used. From this the average injury reduction due to use of a shoulder harness and the number of fatalities and injuries that could have been saved since 1976 by having compulsory installation and use of shoulder harnesses could be estimated.

Given an accident where the pilot was injured not wearing a shoulder harness, it is difficult, if not impossible, to say exactly what his/her injuries would have been had a shoulder harness been worn. This is particularly so for serious and fatal injuries. It is, however, possible to roughly estimate the chance of a particular injury using the available data on the accident and past accident investigations and experience. Therefore, the approach used was for each pilot and co-pilot in the accidents reviewed to estimate the probability of each type of injury, given a shoulder harness had been worn. The method used is demonstrated for several accidents in Appendix D. From these the expected number of each type of injury, given a shoulder harness had been worn, could be found and compared with the observed injuries where a shoulder harness was not worn.

The factors taken into account when determining the injury probabilities were:

- Speed and angle of impact, the position in the survivability envelope described by NTSB [1].

- Type of terrain (water, trees, snow, etc.), the rate of deceleration on impact and escape to safety from aircraft (injuries due to drowning or fire).

- Injuries to other occupants and position of those occupants.

- Impact damage to cabin (liveable area for pilot).

- Time to rescue and season (effect of delays given injuries, hypothermia or death due to exposure).

- Narrative - gauge severity of impact and how injuries occurred, types of injuries and effectiveness of shoulder harness at preventing those injuries (effective for head injuries, but not for injuries to limbs). Was shoulder harness and its likely effect mentioned.

The detailed investigations of small aeroplane accidents and the effect of shoulder harnesses carried out by the NTSB [1] were used as a basis for estimating the injury reduction probabilities. The NTSB give the distribution of the reduction in injuries due to shoulder harness use for the survivable accidents they investigated. These were used as the most likely values when reviewing both the small aeroplanes and helicopter accidents in Canada, but were adjusted up or down within a given range according to the particular circumstances involved in the accident. The NTSB did not distinguish between minor or no injury and it was necessary to estimate probabilities for reductions to no injuries. It was assumed that the effectiveness of shoulder harnesses in reducing minor injuries was similar to the effectiveness of reducing serious injuries. The most likely probabilities and the range of values are given in Table 7.3.

Each of the accident summaries were reviewed and the probability of the pilot receiving each type of injury had he/she been wearing a shoulder harness was estimated. Particular care was taken with accidents involving fatalities as, on average, these accidents contribute most to the benefits of shoulder harnesses in a cost-benefit analysis. From this the probability of each type of injury reduction due to use of a shoulder harness was estimated. The estimated probabilities were entered into a DBASE file for analysis.

Table 7.3 Most Likely Value and Range of Possible Values of Injury Reduction Probabilities due to Shoulder Harness

Injury Reduction due to Shoulder Harness		Probability of Injury Reduction: Likely Value	Likely Range	Average Assigned Value: Aeroplane	Helicopter
Fatal ->	Fatal	0.25		0.41	0.47
	Serious	0.49	(0.10 , 0.80)	0.39	0.38
	Minor	0.26	(0.00 , 0.40)	0.20	0.15
Serious ->	Serious	0.20		0.26	0.32
	Minor	0.60	(0.40 , 0.95)	0.55	0.54
	None	0.20	(0.00 , 0.50)	0.19	0.14
Minor ->	Minor	0.20		0.27	0.27
	None	0.80	(0.40 , 1.00)	0.73	0.73

7.3.2 Estimated Pilot Injury Reduction due to Shoulder Harness

The estimated average injury reduction for pilots in Canada due to the use of shoulder harnesses can be estimated by averaging the assigned probabilities for each type of injury reduction. These average probabilities are given on the right side of Table 7.3 for aeroplane and helicopter accidents. The probabilities are similar to those found by the NTSB (most likely column in Table 7.3), but indicate that the effect shoulder harnesses was estimated slightly conservatively (i.e., its effect was likely underestimated based on the NTSB findings).

The consistency of the two methods of evaluating shoulder harness effectiveness can be compared as follows. The average assigned probabilities (Table 7.3), which are based primarily on the findings of the NTSB, can be used to estimate, for pilots not wearing shoulder harnesses, the likely distribution of injuries had they been wearing shoulder harnesses. This distribution can then be compared with the observed distribution of injuries to pilots using shoulder harnesses (in Figures 7.1 and 7.2). Table 7.4 shows the results of the comparison for the small commercial aeroplane and helicopter accidents. The estimated distribution of injuries had a

shoulder harness been worn are very close to the observed distribution given the shoulder harness was worn for both types of aircraft. Thus, both methods of evaluating the effectiveness of shoulder harnesses give consistent results.

Table 7.4 Comparison of Observed and Estimated Injury Distribution with Shoulder Harness Worn in Survivable Accidents

SMALL COMMERCIAL AEROPLANES

Source of Distribution	Shoulder Harness	Percentage with Injury Type: Fatal	Serious	Minor	None
Observed	Not Used	4.9	11.1	10.8	73.2
Estimated Based on*:	Used				
Av. assigned prob.		2.1	4.8	10.0	83.2
NTSB probabilities		1.2	4.6	10.1	84.0
Observed#	Used	1.1 (0.5)	4.5 (0.9)	9.0 (1.2)	85.4 (1.5)

HELICOPTERS

Source of Distribution	Shoulder Harness	Percentage with Injury Type: Fatal	Serious	Minor	None
Observed	Not Used	3.7	15.0	12.6	68.7
Estimated Based on*:	Used				
Av. assigned prob.		1.7	6.2	12.1	80.0
NTSB probabilities		0.9	4.8	12.5	81.8
Observed#	Used	1.1 (0.6)	13.4 (2.1)	17.1 (2.3)	68.4 (2.8)

* Average assigned probabilities of probability of injury reduction given on left of Table 7.3 and NTSB probabilities given in column titled "Likely Value" in Table 7.3.

\# Standard deviation of observed rate given in brackets.

The NTSB findings on the effectiveness of shoulder harness for small aeroplanes are also applicable for helicopters, but may over-estimate the effectiveness of shoulder harnesses at preventing serious and minor injuries. The injury estimates based on NTSB probabilities are closer to the observed distribution, indicating that the assigned probabilities of injury reduction underestimated the benefit of the shoulder harness.

There were a total of 237 small commercial aeroplane accidents and 53 helicopter accidents since 1976 where the pilot was injured which were classified as survivable and partly survivable. The observed number of injuries to pilots not wearing shoulder harnesses in these accidents and the estimated number of injuries had shoulder harnesses been worn are given in Table 7.5. Given the conservative nature of the assigned probabilities, the estimated number based on both the assigned probabilities and on the average NTSB probabilities are given. As commercial helicopters fly approximately 80% of the total hours flown by helicopters, the injury reduction estimates due to shoulder harnesses in commercial helicopters only would be 80% of the values given in Table 7.5.

Considering small commercial aeroplanes and commercial helicopters, about 32 to 40 lives would have been saved, about 64 fewer pilots would have been seriously injured and about 106 more pilots would have received no injuries had they been wearing shoulder harnesses.

Table 7.5 Estimated Pilot Injury Reduction due to Shoulder Harness (1976-1989)

SMALL COMMERCIAL AEROPLANES

Shoulder Harness Usage and Method	Number of Pilots with Injury Type: Fatal	Serious	Minor	None
Not Worn - Observed	45	98	94	735
Worn - Based on:				
1. Assigned prob.	19	43	88	823
Injury Reduction	27	55	6	-88
2. NTSB prob.	11	42	89	830
Injury Reduction	34	56	5	-95

Table 7.5 Estimated Pilot Injury Reduction due to Shoulder Harness (1976-1989) (Continued)

HELICOPTERS*

Shoulder Harness Usage and Method	Number of Pilots with Injury Type: Fatal	Serious	Minor	None
Not Worn - Observed	11	22	20	238
Worn - Based on:				
1. Assigned prob.	5	11	19	256
Injury Reduction	6	11	1	-18
2. NTSB prob.	3	10	20	258
Injury Reduction	8	12	0	-20

* Reduce by 20% for commercial helicopters only.

As discussed in Section 7.2.1, the pilot may have been able to survive had he/she been wearing a shoulder harness in some accidents classified as non-survivable. Therefore, the above estimate of 32 to 40 lives saved should be considered a conservative estimate.

7.3.3 Effectiveness of Shoulder Harnesses of Co-Pilot's Seat

The effectiveness of shoulder harnesses should be similar for pilots and the person occupying the co-pilots seat as both are located in front seats and would experience similar deceleration forces and intrusion into the cabin on impact. Evaluation for the co-pilot's seat is made complicated by a number of things:

1. many small aeroplanes do not require a co-pilot and some can be flown with or without a co-pilot (e.g., training aircraft),
2. the co-pilot's seat is often occupied by a passenger,
3. the CASB accident summaries do not clearly and consistently indicate if the aeroplane has a seat for a co-pilot or if a passenger is occupying the co-pilot's seat.

Injuries to the occupant of the co-pilot's seat would be reduced by compulsory installation and usage of shoulder harnesses in the co-pilots seat. The reduction in co-pilot injuries can be found with CASB accident summaries using the approach in (ii), but it is not possible to determine the passenger component of injury reduction from these summaries. Therefore, only the reduction in co-pilot injuries were estimated.

The same approach for estimating probabilities of injury reduction, based on the NTSB values given in Table 7.3, was used for co-pilots injured in small commercial aeroplane and helicopter accidents since 1976. The observed number of injuries to co-pilots and the estimated injuries had they worn shoulder harnesses is given in Table 7.6. About four fatalities and seven serious injuries would have been prevented, and about 15 fewer co-pilots would have been injured had all co-pilots being wearing shoulder harnesses. In addition, injuries to passengers occupying the co-pilot's seat could have been reduced by compulsory installation and usage to shoulder harnesses in the co-pilot's seat. However, the usage rate may be less for passengers than for pilots (as for passengers in cars), thus reducing their overall effectiveness.

Table 7.6 Co-Pilot Injury Reduction due to Shoulder Harness Usage in Small Commercial Aeroplanes and Helicopters (1976-1989)

Shoulder Harness Usage and Method	Number of Co-Pilots with Injury Type: Fatal	Serious	Minor	None
Not Worn - Observed	6	13	17	
Worn - Based on:				
1. Assigned prob.	3	8	10	16
Injury Reduction	3	5	7	-16
2. NTSB prob.	2	6	13	15
Injury Reduction	4	7	4	-15

7.4 Conclusions

The following conclusions can be reached from the accident analysis.

- Shoulder harnesses are very effective at reducing the severity of injuries to pilots in both small aeroplane and helicopters accidents. The effectiveness of shoulder harness is about the same for both categories of aircraft.

- Approximately 38 fatalities and 64 serious injuries could have been prevented had all pilots of small commercial aeroplanes and commercial helicopters worn shoulder harnesses since 1976. A further 4 fatalities and 7 serious injuries could also have been prevented to co-pilots by shoulder harness usage.

- The effectiveness of compulsory installation of shoulder harnesses would be significantly reduced if wearing of shoulder harnesses was not also made compulsory.

- Pilots who do not wear available shoulder harnesses are involved in more serious accidents than pilots who wear available shoulder harnesses.

8. THE COST OF SHOULDER HARNESS RETROFIT KITS

8.1 Methodology

Research was carried out using the January 15, 1989 aircraft register for commercial aircraft of 12 500 lbs. or less. Because FAA amendments 23-19 and 91-139 required shoulder harnesses in the front seats of all small airplanes manufactured after July 15, 1978, it was beneficial to separate aircraft manufactured before 1978, in 1978, and, after 1978. This meant that the number of aircraft involved in this study could be reduced by the number of aircraft already fitted. It was impossible, however, to determine the number of aircraft manufactured before 1978 which may have been purchased with shoulder harnesses installed as an option, and, which may have been retrofitted due to owner's preference. Furthermore, some manufacturers had introduced the shoulder harness as standard equipment on some models before the 1978 required date. Therefore, the number of aircraft remaining is the highest possible number which would have to be retrofitted.

In order to acquire cost information, it was necessary to identify and organize the data, search for proper contacts, make telephone calls to solicit information (many calls had to be re-routed, many were fruitless), make follow up calls to clarify or obtain additional information, and sometimes, go through the whole process again. In some cases, great effort resulted in no or very little information.

The following aircraft manufacturers were contacted: Cessna, Piper, DeHavilland, Rockwell, Gulfstream, Aero Commander, Fairchild, Twin Commander, Bell, McDonnell Douglas (Hughes), and Sikorsky. Many distributors/suppliers and operators were also contacted, quite a few were in the United States.

The company names of those who provided information on acquisition and installation costs of shoulder harnesses are indicated as footnotes on the appropriate price lists.

Some parts distributors were reluctant to spend time providing estimates for this study unless they were compensated. In some cases, the work involved many hours at identifying individual aircraft parts, and then verifying parts lists prices which sometimes meant contacting manufacturers. To further compound the problem, hardware requirements and prices are dependent upon the model and serial number of an aircraft. So, for any given model, there may be different parts lists and naturally different prices. It is an extremely long process to go through especially when there is no special shoulder harness kit available.

Furthermore, distributors and suppliers understand this study is done under contract for Transport Canada and therefore is remunerated[2]. They believe they should be compensated for their troubles as well.

8.2 Manufacturers And Distributors

Some manufacturers provide shoulder harness retrofit kits for installation in their products. These are Beech, Cessna, Piper, DeHavilland, Pilatus Britten Norman, Bell, McDonnell Douglas (Hughes), and Aerospatiale. However, some of their aircraft models do not have kits as such, but manufacturers may be able to provide all the necessary hardware. Some kits for specific aircraft models are provided by equipment manufacturers such as Kosola and Associates, WAG aero and Aeronautical Accessories; some of these kits are generic and fit in more than one aircraft model.

Cessna: Cessna provides kits for single engine models. There are no specific kits for its twins, but parts may be ordered separately that would meet the requirement. Stocks for its older model twins as well as its models manufactured in smaller numbers may be depleted. In such cases, shoulder harnesses would have to be made to order and would be much more costly than indicated in the table.

All of the Cessna later series were manufactured with the shoulder harness structure therefore making it easy to install the harness. Older series with no structure would require more time for installation and would probably require additional hardware.

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2 Publicized in CANADIAN AVIATION October '89.

WAG aero provides generic kits for Cessna models 120 to 210 inclusive.

Beech: Except for older models, Beech provides complete retrofit kits. These kits are all inclusive and require no additional hardware.

Piper: Piper provides kits for only a few of its models. The company is presently working at completing kits for the remainder. However, all the necessary parts may be ordered to meet the requirements of the kits.

Later series of some models have the shoulder harness structure installed. Older series would require more hardware and installation time.

Kosola and Associates provides kits for certain Piper models.

DeHavilland: The company provides shoulder harness kits for its DHC6 only. It sold its rights to the DHC2 and DHC3 to Viking Air Ltd.

Kits for the DHC2 and DHC3 are available through Viking Air Ltd., Victoria, B.C.

Bell: All Bell helicopters manufactured after January 1981 have been equipped with shoulder harnesses as standard equipment.

Aeronautical Accessories provides kits for BH06s.

Aerospatiale: They provide kits for their models. Kits for the S316 and S318 do not have inertia reel.

Others: Viking Air Ltd., has acquired the rights to the Beaver DHC2 and the Otter DHC3 from DeHavilland. The type of harness provided is the same type as the one provided to Transport Canada Flight Services for its DHC2s. It has no inertia reel.

Leavens Aviation Inc., Mississauga, Ontario, has a Certificate of Compliance for an AMS 1000 Hooker harness which they advertise as generic to all aircraft types. The price is $56.00 per seat, but it does not include the seatbelt or any hardware. There is no inertia reel.

Airtech Canada, Peterborough, Ontario, will sell and install shoulder harnesses for all aircraft models where the aircraft manufacturer does not provide shoulder harness kits. The price for the shoulder harness is $60.00 per seat. If the lap belt has to be replaced, there is an additional charge of $40.00. There is no hardware included. It is estimated that four person/hours is required for an installation where there is no problem attaching the harness.

8.3 Government Agencies

8.3.1 Transport Canada

The Superintendent Air Carrier Inspection (Rotorcraft And Small Aeroplanes), Mr. Pat Clermont, confirmed that small air carriers including helicopter operators, are not requested through their Operating Certificates to have shoulder harnesses in the front seat of their aircraft.

8.3.2 Federal Aviation Administration

The FAA has published a federal requirement, final rule Nov 13/89, Vol. 54 No. 217 page 4730 amendment 27-25 and 29-29 effective Dec 13/89 for all occupants of helicopters. There is a Notice of Proposed Rulemaking (NPRM) Vol. 54 No 235 page 50688, requiring all seats in all rotary wing aircraft to have shoulder harness. The FAA contact is Mr. Jim Majors at 817-624-5117.

8.4 Retrofit Costs

Tables of shoulder harness retrofit costs were constructed for popular aeroplane types, for helicopters and for miscellaneous airplanes and are given in Appendix A. They are:

Table 1: Cessna
Table 2: Beech
Table 3: Piper

Table 4: Rockwell
Table 5: DeHavilland
Table 6: Gulfstream
Table 7: Pilatus Britten Norman
Table 8: Helicopters
Table 9: Miscellaneous airplanes

These tables indicate the number of aircraft for each model, the model, the price of the shoulder harness, the installation man/hours and costs, the availability from the manufacturer and other sources, the total price of the retrofit and remarks.

Tables do not include price estimates. All prices indicated have been quoted by qualified sources which are identified in footnotes.

Prices quoted are for the two front seats and do not include Federal sales tax of 11.25% and Provincial sales tax of 8% (Ontario). Some of the prices were quoted by United States sources; it is not known if there are any State taxes or import taxes. Where more than one price is indicated, the price depends on the serial number of the aircraft. Costs for man/hours have been calculated at $52.00 per hour (Field Aviation Ltd.rates). Prices quoted in U.S. currency have been converted to Canadian dollars using 1.1820 as exchange rate.

The man/hours requirements for installation is extremely difficult to estimate because there are many variables to consider. For instance an aircraft modification shop could face different challenges depending on the serial number of a given aircraft model. Therefore, shops are reluctant to estimate without seeing the aircraft and kits to be installed. Where quoted, the man/hours estimate is for both front seats.

Some manufacturing companies have been sold in whole or in part more than once, have changed names and have gone out of business. To trace the company holding rights to a certain model becomes very difficult. In these cases, it is best to look for information on generic type shoulder harnesses. Availability of shoulder harness information from other than

major manufacturers is next to impossible to acquire especially for older aircraft models. Here, the challenge is to find shoulder harness manufacturers with Supplemental Type Certificate (STC). These companies usually produce shoulder harnesses generic to two, perhaps three aircraft models. Again, it is extremely difficult to find shoulder harness kits for the older and more obscure aircraft models.

9. COST-BENEFIT ANALYSIS

9.1 Methodology

A cost-benefit analysis was used to determine whether retrofitting shoulder harnesses for the pilot and co-pilot seats in small commercial aeroplanes and commercial helicopters in Canada could be justified on financial grounds. The analysis was carried out separately for small commercial aeroplanes and helicopters. The approach used was to:

- Identify those aircraft registered in Canada which possibly do not have shoulder harnesses installed and, for those aircraft, estimate the probability that a shoulder harness is installed.
- For each of those aircraft, estimate the net present value of injuries and fatalities prevented by the installation and use of shoulder harnesses over the aircraft's likely life span.
- Calculate the cost of retrofitting shoulder harnesses in each aircraft.
- Calculate the cost-benefit ratio for each aircraft.
- Calculate the overall cost-benefit ratio by summing the estimated savings and retrofit costs over all aircraft.
- Compare with U.S. cost-benefit analysis results for shoulder harnesses retrofit.

9.2 Shoulder Harness Retrofit Requirement

9.2.1 Aircraft Manufactured with Shoulder Harnesses

More than half the small commercial aeroplanes in Canada presently do not have shoulder harnesses installed. Installation of shoulder harnesses is not compulsory for aeroplanes manufactured in Canada and, until mid-1978, aeroplanes manufactured in the U.S. did not require shoulder

harnesses either. All aeroplanes manufactured in the U.S. after mid-1978 in use in Canada can be assumed to have shoulder harnesses installed. Less than 2% of small commercial aeroplanes were manufactured outside North America and these are assumed to not have compulsory installation of shoulder harnesses.

Information on all aircraft currently registered in Canada is kept on the Canadian Aircraft Registry System (CARS). This database includes the following data useful for this project:

- aircraft make and model,
- aircraft serial number,
- maximum takeoff weight,
- year and country of manufacture, and
- category of aircraft (fixed wing, helicopter, etc)
- usage category (commercial, private, etc.)

The year and country of manufacture were used to determine whether an aeroplane was fitted with a shoulder harness when built. It was assumed that half of the aeroplanes on the registry built in 1978 had shoulder harnesses fitted when built. The year and country of manufacture were not recorded in CARS for 2% of the aeroplanes and, as the registration numbers were generally similar to those of older aeroplanes, it was assumed that they did not require shoulder harnesses when built. A breakdown of relevant characteristics of small commercial aeroplanes in Canada is given in Table 9.1.

Table 9.1 Small Commercial Aeroplanes Registered in Canada in June, 1989

Manufactured Country	Year	Number of Aeroplanes	Shoulder Harness Required when Built
U.S.	before 1978	2497	No
	during 1978	237	50% Yes
	after 1978	674	Yes
	Unknown	42	No
Canada	All years	564	No
Other	All years	66	No
Total	All years	4080	19% Yes

Thus, only 19% of small commercial aeroplanes currently on register in Canada were required to have shoulder harnesses installed when they were built.

There have been no requirements in Canada or the U.S. to have shoulder harnesses installed in helicopters when manufactured. A number of types have shoulder harnesses as standard equipment (see Appendix A) and 8.3% of helicopters currently on the aircraft register were manufactured with shoulder harnesses installed.

9.2.2 Shoulder Harness Installation After Manufacture

Despite the lack of a requirement for shoulder harnesses in Canadian and pre mid-1978 U.S. manufactured aircraft, shoulder harnesses are installed in many of these aircraft. The accident/incident database, AIDS, maintained by CASB includes a variable indicating whether a shoulder harness was installed for the pilot and co-pilot for each accident. The numbers of small commercial aircraft involved in accidents and built prior to 1978 with and without pilot shoulder harnesses are given in Table 9.2. The availability of shoulder harnesses for the co-pilot's seat was not recorded for most of those accidents. In only 6% (2 of 33) of cases where the both the pilot and co-pilot shoulder harnesses installation was recorded, was a shoulder harness installed for the pilot, but not for the co-pilot.

Table 9.2 Shoulder Harness Installation for Pilot's Seat in Small Commercial Aircraft Manufactured Prior to 1978 Involved in Accidents*

Shoulder Harness	Number	% of Total	% of Total where Year Built coded
Installed	800	34%	43%
Not installed	860	37%	57%
Not coded	188	21%	
Year Built not coded	496		

* Includes both fixed wing and rotary, but CASB data indicates that shoulder harness installation rates in the two types of aircraft are very close.

It is reasonable to assume that the installation rates given in Table 9.2 would be similar to the rate for all aircraft which did not require shoulder harnesses when manufactured. In 34% of accidents the aircraft was built prior to 1978 and had shoulder harnesses installed. However, year of manufacture was not recorded in 21% of accidents. Considering only those accidents where year of manufacture was known to be before 1978, 43% of the aircraft had shoulder harnesses installed. Thus, roughly 40% of aircraft not manufactured with shoulder harnesses have subsequently had them installed. Approximately 2000 small commercial aeroplanes and 450 commercial helicopters in Canada do not currently have shoulder harnesses installed.

In calculating the costs and benefits of retrofitting shoulder harnesses, initially it was assumed that 60% of aeroplanes without shoulder harnesses when manufactured will require retrofitting, but the particular aeroplanes were not known. The costs and benefits were determined for each aircraft not manufactured with shoulder harnesses and were summed to determine overall costs and benefits. As each aeroplane not manufactured with shoulder harnesses has a 0.60 probability of now requiring retrofitting, both the total costs and total benefits were multiplied by a factor of 0.60. The probability therefore cancels out when calculating the cost-benefit ratio. Thus, the cost-benefit ratio of shoulder harness retrofit, is not dependent on the exact proportion of these aeroplanes requiring retrofit.

A similar approach was used for helicopters, but the percentage of those helicopters not manufactured with shoulder harnesses requiring retrofit was estimated from CASB accident data as a function of the year of manufacture. The percentages requiring shoulder harness installation are given in Table 9.3.

9.2.3 Shoulder Harness in Co-pilot's Seat

The proposed requirement for shoulder harnesses is for both the pilot and co-pilot seats in each small commercial aircraft. Single seater aeroplares, which comprise 7% of the small commercial aeroplane fleet in Canada, require only one shoulder harness. Almost all small aeroplanes with two or more seats have two front seats which are for use by a pilot and co-pilot, although a co-pilot is usually not required to

fly the aeroplane. Many have a flight control stick for both front seats. Therefore, in calculating the costs and benefits, shoulder harnesses are assumed to be required for both front seats of all small commercial aeroplanes and commercial helicopters with two or more seats. Note that the co-pilot's seat is often occupied by a passenger and benefits of the shoulder harness are calculated irrespective of who is occupying the seat.

Table 9.3 Percentages of Helicopters Requiring Shoulder Harness Retrofit Estimated form CASB Accident Data

Year of Manufacture	Require Retrofit	Year of Manufacture	Require Retrofit
1962 & before	64%	73	62%
63	50%	74	43%
64	74%	75	53%
65	56%	76	32%
66	55%	77	50%
67	60%	78	50%
68	76%	79	30%
69	58%	80	34%
70	55%	81	22%
71	51%	82	38%
72	64%	1983 & after	33%

9.3 Retrofit Costs

The retrofit costs for each aircraft type given in Appendix A were used in the cost-benefit analysis. The costs, however, could not be determined for 57 aircraft models (about 15% of registered small commercial aeroplanes and helicopters) and it was necessary to estimate these costs form available data. The known shoulder harness retrofit costs for both front seats ranged from $264 to $4,766 for aeroplanes and the average cost over the 62 aircraft types for which costs were determined was $2,163. For helicopters, costs ranged from $1,883 to $6,974 (latter for kit only) with an average cost of $3,750. Retrofit costs vary greatly between aircraft manufacturers, but the variation is usually less between models from the same manufacturer. Some aviation workshops fit shoulder harnesses generic to all aircraft types for as low as $330 (provided the lap belt does not need replacing and there are no problems attaching the harness). Therefore, the following criteria was used when estimating the retrofit costs:

- Where costs for other models of aircraft for the same manufacturer are known, use the maximum of these costs.

- Otherwise, use three values which effectively cover the range of likely costs and test these values in a sensitivity analysis. The three costs used were:

  1. For Aeroplanes

     $2,000 - approximately the average known cost,
     $800 - price for generic model allowing for replacement of lap belt and/or some installation problems,
     $4,000 - for only one model of aeroplane was the price greater than this.

  2. For Helicopters

     $3,750 - approximately average known cost,
     $2,650 - only one model helicopter has cheaper retrofit cost,
     $7,000 - only one model helicopter has a more expensive retrofit cost.

9.4 Benefits

The following assumptions were made in calculating the benefits of shoulder harness installation:

- The accident rate and injury distribution in accidents for aircraft with and without shoulder harnesses remain at current levels for aircraft requiring retrofit over the remaining years the aircraft are flown.

- Shoulder harnesses continue to be worn at the current usage rates (benefits also found for 100% usage rates).

- The occupancy rate of the co-pilot's seat remains constant.

- The injury probability for occupants of the co-pilot's seat are the same as for the pilots (as both are in the front seats).

The estimated savings from the installation and use of shoulder harnesses in an aircraft are found by calculating for each year the aircraft is likely to fly,

- the probability of the aircraft having an accident in a given year,
- the expected reduction in injury to the pilot and occupant of co-pilot's seat in an accident due to the shoulder harness, and
- the value of the injury reduction in today's dollars.

Total savings for an aircraft is then found by summing over the years it is likely to continue flying.

9.4.1 Accident Probability

Small commercial aeroplanes are used primarily for charter/contract and specialty (including training) type operations. In a recent study by SYPHER:MUELLER [4] on Canadian Aviation Safety, the accident rate of small contract/charter fixed wing operations was found to be 7.7 accidents per 100,000 hours flown and 10.4 for specialty fixed wing operations (over period 1983 to 1987). As contract/charter and specialty operations each constitute about half of the small fixed wing commercial operations, the average accident rate is 9.0 per 100,000 hours flown. The accident rate for helicopters over the period 1983 to 1988 is 10.7 per 100,000 hours flown (CASB 1988 Annual Report). The rate varies with type of usage from 55 for speciality type operations to 6.2 for contract/charter operations.

The accident rate should be based on the number of departures rather than hours flown, but the required departure data is not available. Provided the average flight time per departure remains approximately constant, use of accident rate per hours flown will be adequate.

The time period over which aeroplanes currently registered in Canada would be expected to fly depends primarily on the current age of the aeroplanes. As shown in Figure 9.1, there are very few aeroplanes over forty years old on the register, but there are still a significant number between 30 and 40 years old. It was therefore assumed that an aeroplane will continue to be flown until it is 40 years old or until it has

an accident. Given the current usage and accident rate there is only a 30% chance of an aeroplane flying 40 years without an accident. Thus, using the assumptions for the cost-benefit analysis, only a third of the aeroplanes would be expected to fly for the full 40 years. It is also assumed that aeroplanes currently on the register over 38 years old will be flown for another 3 years.

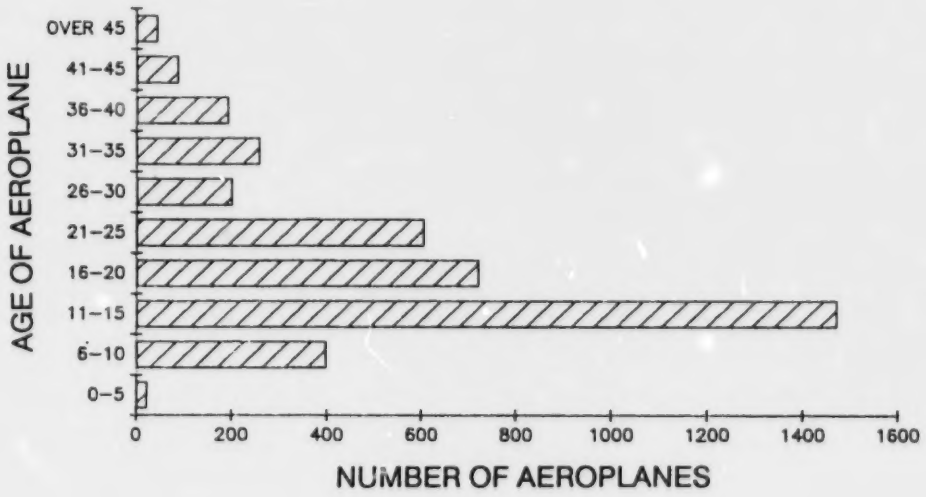

Figure 9.1 Age Distribution of Small Commercial Aeroplanes in Canada

Similarly there is a large drop in the number of commercial helicopters built prior to 1963 and it was therefore assumed that helicopters would continue to be flown until they are 25 years old or have an accident. Helicopters over 23 years old are assumed to be flown for another three years.

The probability of an aircraft having an accident in any given year is equal to the product of the accident rate per hour flown and the number of hours flown. The average hours flown by small commercial aeroplanes in Canada was found using operational data published by Statistics Canada [5] for levels 3, 4 and 5 air carriers. These carriers operate almost all (about 98%) of the small commercial aeroplanes in Canada. The most recently published hours flown by each level and estimated values for 1989 are given in Table 9.4. The level 3 and, too a much lesser extent, level 4 carriers operate

scheduled services and these constitute 18% of their hours flown. However, these are likely flown using the large aeroplanes (over 5,700 kg) owned by these operators and have therefore not been included in Table 9.4. The average usage per aeroplane per year was found by estimating the total number of hours flown by these carriers in 1989 and dividing by the number of small commercial aeroplanes in 1989. An average value of 348 hours per aeroplane per year was found.

Table 9.4 Hours flown by Operators of Small Commercial Aeroplanes in Canada

Level of Operator	Base Year	Type Operation	Hours Flown	Estimated Hours Flown in 1989*
3	1987	Specialty	143,389	151,000
		Cont./Chart.	371,144	390,000
4	1987	Specialty	273,791	388,000
		Cont./Chart.	258,727	272,000
5	1983	Specialty	184,035	213,000
Total				1,413,000

* An average annual increase of 2.5% assumed

The average hours flown per helicopter over the period 1985 to 1987 was estimated from data provided by Statistics Canada [5] to be 475 per year.

The usage of aircraft varies considerably between aircraft and aircraft operator and also varies with aircraft age. Based on data collected by SYPHER:MUELLER in a recent study on Aviation Safety in Canada [4], the average hours flown decreases as aeroplane age increases as shown in Figure 9.2. The figure is based primarily on large (over 5,700 kg) aeroplanes, but a decline would be also be expected for small aeroplanes. The rate of decline may be less for small aeroplanes as they are less sophisticated and more economical to keep a small aircraft airborne. The rate of decline in hours flown was initially based on Figure 9.2 and the effect of a lower rate of decline was tested in the sensitivity analysis.

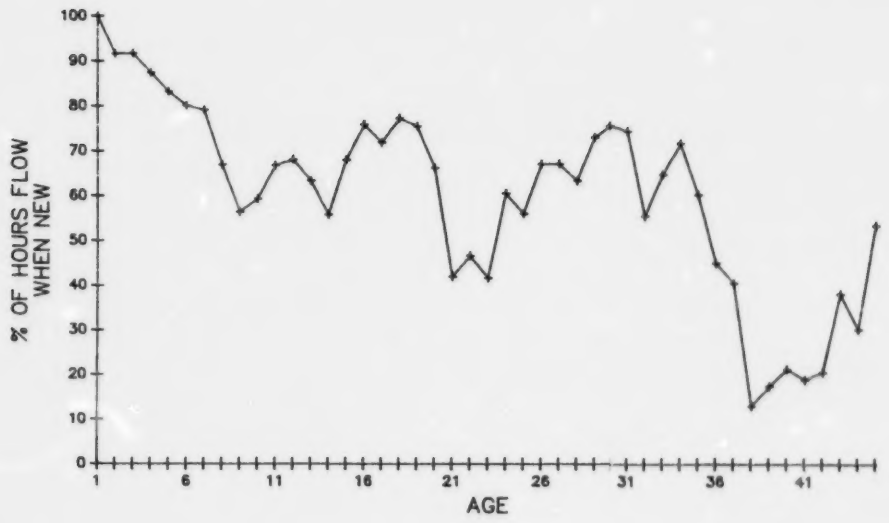

Figure 9.2 Decline in Average Hours Flown with Average Aeroplane Age for Commercial Aeroplanes in Canada

For the purposes of this study, when calculating the probability of an accident, the average hours flown was assumed to decrease by 50% over the 40 year lifetime of the aeroplane and a similar rate of decline was used for helicopters (31% over 25 years). The number of hours flown was estimated for any given year for each aircraft on the register by:

Hours Flown = 464 - 5.8 x Age for aeroplanes
Hours Flown = 490 - 5.4 x Age for helicopters

Using this expression, the total hours flown by small commercial aeroplanes on register in 1989 is very close to the total value given in Table 9.3.

The probability of an aeroplane, currently on register, having an accident in 1990 year is calculated by

$$P(\text{Accident in 1990}) = 9.0 \times 10^{-5} \ (464 - 5.8\ (1990 - \text{Year Built}))$$

As all aeroplanes currently on register are assumed to fly in 1991 provided they were not involved in an accident the previous year, the probability of the aeroplane having an accident in 1991 is

P(Accident in 1991)

= P(No accident in 1990) x
  P(Accident in 1991 given no accident in 1990)

= (1 - P(Accident in 1990)) x
  9.0×10^{-5} (464 - 5.8 (1991-Year Built)

Continuing with this reasoning, the probability of an aeroplane currently on register being involved in an accident in year n is

P(Accident in year n)

= P(No accident before year n) x
  P(Accident in 1991 given no accident in 1990 or before)

= $(1 - \Sigma$ P(Accident in year i)) x 9.0 x
  10^{-5} (464 - 5.8 (n-Year Built))

where the summation is over the years i = 1 upto n - 1

Similarly, the probability of a helicopter currently on register being involved in an accident in year n is

= $(1 - \Sigma$ P(Accident in year i)) 10.7 x
  10^{-5} (550 - 6.1 (n-Year Built))

9.4.2 Value of Injury Prevention

The effectiveness of shoulder harnesses at reducing injuries is discussed in Section 7. The distribution of pilot injuries in small commercial aeroplane accidents is given in Figure 7.1. The proportions represent the expected number of a particular type of injury to the pilot given shoulder harness installation and usage. The expected reduction in injuries due to the shoulder harnesses was found by subtraction as shown in Table 9.5. The injury reduction rates for helicopters were found in a similar way and are also given in Table 9.5.

Table 9.5 Expected Injury Reduction due to Shoulder Harness Installation and Usage

Shoulder Harness	Death	Serious Injury	Minor Injury
AEROPLANE			
Not Installed	0.142	0.091	0.086
Installed	0.102	0.067	0.097
Expected Reduction	0.040	0.024	-0.011
Lower bound on reduction*	0.007		
100% Usage	0.077	0.042	0.083
Expected Reduction	0.065	0.049	0.003
Lower bound on reduction*	0.024		

Shoulder Harness	Death	Serious Injury	Minor Injury
HELICOPTER			
Not Installed	0.141	0.133	0.115
Installed	0.076	0.128	0.152
Expected Reduction	0.065	0.005	-0.037
Lower bound on reduction*	0.015		
100% Usage	0.057	0.128	0.163
Expected Reduction	0.084	0.005	-0.048
Lower bound on reduction*	0.035		

* Lower bound of 95% confidence interval for reduction in probability of death due to shoulder harness

Based on these injury probabilities, the retrofit of shoulder harnesses in the pilot and co-pilot seats of small commercial aeroplanes in Canada can be expected to save about 81 lives and prevent a further 48 serious injuries over the life span of these aeroplanes. If the wearing of available shoulder harnesses was made compulsory and 100% usage was achieved, 131 fatalities and 99 serious injuries would be prevented. A further 18 to 24 lives would be saved in commercial helicopter accidents.

To carry out any form of cost-benefit analysis to assess the viability of safety improvements, it is necessary to place an economic value on the prevention of death and injury. A review of these values was undertaken as part of a recent project to evaluate the effectiveness of Crash Fire Rescue Services at Canadian airports [6]. A range of values were used in that study and the same values were used in the current study. They are:

Life saved:	$2,500,000	Range:	$1,000,000 to $5,000,000
Serious injury:	$ 660,000	Range:	$ 300,000 to $1,000,000

A value for the prevention of a minor injury was not used in the Crash Fire Rescue Service study and a value of $3,000 was set arbitrarily, with a lower range value of zero. The cost-benefit analysis is extremely insensitive to the value of minor injury prevention.

The expected savings due to the installation and use of a shoulder harness by the pilot given an accident occurs are given in Table 9.6.

Table 9.6 Expected Savings Due to the Installation and Use of a Shoulder Harness by the Pilot Given an Accident Occurs

Aircraft Type	Shoulder Harness	Value of Injury Prevention (Range)
Aeroplane	Current Usage:	$115,800 ($47,200 , $223,900)
	100% Usage:	$194,800 ($79,700 , $374,000)
Helicopter	Current Usage:	$165,700 ($66,500 , $329,900)
	100% Usage:	$213,200 ($85,600 , $424,800)

Expected savings in years after 1989 were discounted using the net present value (NPV) technique. The present value of savings in year n were calculated as follows:

$$NPV = Savings / (1 + i)^{n-1}$$

where i is the discount rate. Discount rates of 5% and 10% were used. The use of NPV greatly reduces the value of savings after a number of years. For example, after 30 years savings are reduced by a factor of 4 for a 5% discount rate and by a factor of 20 for a 10% discount rate. Thus, assumptions about aircraft accident rates, life span and usage are not nearly as critical for the latter years as they contribute least to the benefits in these years.

The value of expected savings due to the use of a shoulder harness are assumed to be the same for the occupant of the co-pilot's seat as for the pilot for those aircraft requiring two shoulder harnesses. The occupancy rate of the co-pilot's seat could not be determined using available data in Canada. However, 22% of small commercial aeroplane accidents and 27% of helicopter accidents in Canada occurred with only a pilot onboard. Thus, the occupancy rate of the co-pilots seat must be less than 78% and 73% for aeroplanes and helicopter accidents, respectively, and the occupancy rate of the co-pilots seat in helicopters is likely to be less than that in aeroplanes. The occupancy rate given by Pailen-Johnston [2] for U.S. small aeroplanes was used for aeroplanes and a slightly lower value was used for helicopters. In their analysis, both front seats were occupied in 2806 of the 5050 accidents investigated, i.e. in 56% of accidents. As 7% of the aeroplanes have only one front seat, 60% of the aeroplanes with two front seats have them both occupied. Thus, the NPV of expected savings for pilots was increased by a factor of 1.60 for those aeroplanes with two front seats. The expected savings were increased by a factor of 1.5 for helicopters.

The benefits by year are shown in Figure 9.3 for shoulder harness retrofit to a 13 year old aeroplane, the most common age of small commercial aeroplanes, and for a 30 year old aeroplane. The sharp decline in benefits is due to the declining value of future savings and the lower benefits for the older aeroplanes are due to the lower utilization rate of older aeroplanes.

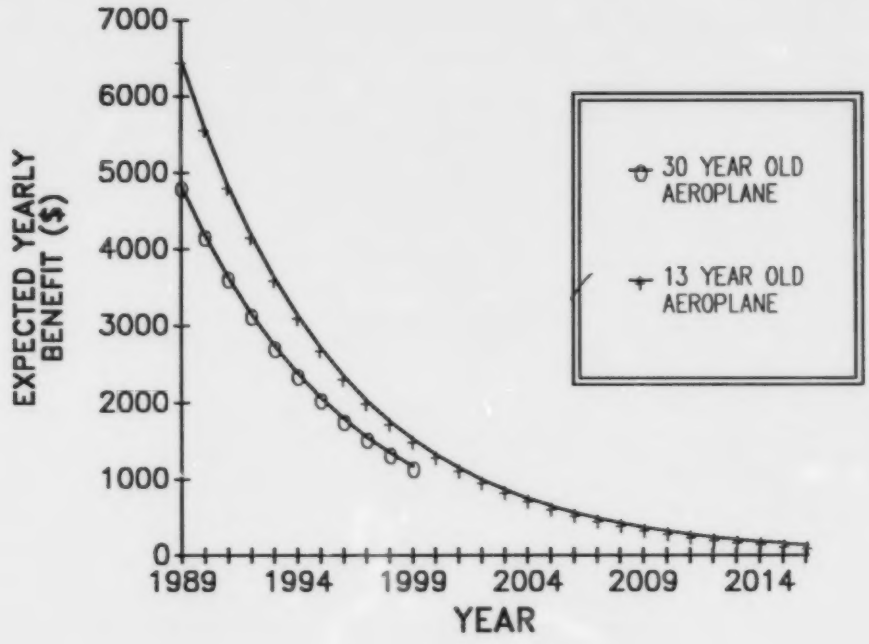

Figure 9.3 Benefits of Shoulder Harness Retrofit for a 13 and 30 year old Aeroplane*

* NPV using 10% discount rate and current shoulder harness usage rates. Area under the curve represents total benefits.

9.5 Cost-Benefit Ratio

9.5.1 Ratio by Age of Aircraft

The costs and benefits of shoulder harness retrofit were estimated for each aircraft (computer program is given in Appendix E). The cost-benefit ratio depends on the type of aircraft, as the retrofit cost varies with aircraft type, and on the age of aircraft. Values of the cost-benefit ratio for a range of aircraft ages using a 10% discount rate, current shoulder harness usage rates and a retrofit cost of $2,000 for aeroplanes and $3,750 for helicopters (approximately average costs) are given in Table 9.7. These cost-benefit ratio's are

reduced by a factor of about 2.5 if the lower values of injury prevention are used or by a factor of 2 if the higher default shoulder harness retrofit cost are used. Thus, even for old aircraft, the retrofitting of shoulder harnesses is cost effective provided that the aircraft will be used for several more years at typical utilization rates (about 230 flying hours per year for aeroplanes, 395 for helicopters).

Table 9.7 Cost-Benefit Ratio for Shoulder Harness Retrofit Given Current Age of Aircraft*

Age	5	10	15	20	25	35	38+
Aeroplane Ratio	26	25	23	21	18	9	5
Helicopter Ratio	24	22	18	13	8		

* Using a 10% discount rate, the current shoulder harness usage rate and a retrofit cost of $2,000 for aeroplanes with two front seats and $3,750 for helicopters.

9.5.2 Overall Ratio

The overall cost-benefit ratio was found by summing the costs and benefits over aircraft requiring shoulder harness retrofit. This ratio was estimated for various combinations of shoulder harness usage, value of injury prevention and NPV discount rates for both types of aircraft and the results are given in Table 9.8.

Actual shoulder harness retrofit costs were unknown for 15% of aircraft and for these aircraft a default cost (see Section 9.3) was used. The sensitivity of the overall cost-benefit ratio to deviations from the medium default retrofit cost was tested. For aeroplanes, use of the high default value of $4,000 decreased the ratio by 15% and use of the low default value of $800 increased the ratio by 11%. Similarly, use of the high and low default retrofit costs for helicopters changed the cost-benefit ratio by -13% and 6%, respectively. Thus, the results are fairly insensitive to the choice of default retrofit cost.

Table 9.8 Cost-Benefit Ratio for Retrofit of Shoulder Harnesses in Small Commercial Aircraft in Canada#

Discount Rate	Shoulder Harness Usage Rate	Value of Injury Prevention Low	Medium	High	Lower Bound on prob.*
AEROPLANES					
5%	Current	12	30	59	14
	100%	21	51	98	31
10%	Current	9	23	44	11
	100%	16	39	74	24
HELICOPTERS					
5%	Current	6	15	31	7
	100%	8	20	40	11
10%	Current	5	13	26	6
	100%	7	17	33	10

* Lower bound on reduction in fatal injury probability due to shoulder harness given in Table 9.4 (using medium values of injury prevention).

\# Unknown retrofit costs assumed to be medium value of $2,000 for aeroplanes, $3,750 for helicopters.

The effect on the cost-benefit ratio of the assumption that hours flown decline for older aircraft by a factor of two over a forty year period was tested. As, on average, hours flown would not increase as the aeroplane got older, the cost-benefit ratio was found assuming no decline in hour flown with age. The cost-benefit ratio for a 10% discount rate, current shoulder harness usage rates, the medium values of injury prevention and default retrofit cost was calculated to be 25 for aeroplanes and 14 for helicopters. This compares with values of 23 and 13, respectively, found assuming a decline in hours flown with increasing aircraft age. Thus, the assumption of a decline in usage with increasing age of aircraft has little effect on the cost-benefit ratio and leads, if anything, to a slightly conservative estimate of the cost-benefit ratio.

9.5.3 Comparison with the U.S.

A cost-benefit analysis for the retrofitting of shoulder harnesses in all seats without them in all small aeroplanes in the U.S. was done by Pailen-Johnston [2]. They obtained a cost-benefit ratio of only 0.085, indicating that the retrofitting costs outweighed the present value of savings by a factor of 12. This result is vastly different from the ratios found for Canadian aeroplanes given in Table 9.6. The reasons for the difference are explored below.

As discussed in Section 7, Pailen-Johnston compared the fatality rate of front seat occupants in aeroplanes manufactured prior to mid-1978 with those manufactured after that date and found no significant difference. From this they concluded that shoulder harness installation did not reduce the likelihood of being killed in a small aeroplane accident. They did, however, find a small reduction in the chance of severe injury due to shoulder harnesses. Their analysis did not consider whether the shoulder harnesses in post-1978 aeroplanes were used or the extent of shoulder harness installation and use in pre-1978 aeroplanes. The Canadian data shows a large significant reduction in the likelihood of being killed or severely injured due to shoulder harness use. These reductions are very similar to those found by detailed accident investigations conducted by the NTSB [1].

The U.S. study considered the economic justification for retrofitting shoulder harnesses in all seats, not just the pilot and co-pilot seats as is the case in the this study. Since the occupancy rate of the passenger seats is less than that of the pilot and co-pilot seats (as the pilot seat is always occupied), the benefits of shoulder harnesses would be less for those seats. In addition, the effectiveness of shoulder harnesses is likely to be greater for the front seats for two reasons:

- the impact damage is usually more severe to the front of the aeroplane, and
- the objects that the front seat occupant's head is likely to contact (e.g., the control stick and instrument panel) causes more severe injuries than those for back seat occupants (usually the cushioned seat in front).

Pailen-Johnston incorrectly calculated the expected number of serious injuries in the cost-benefit study for the U.S. They calculated the average serious injury rate per accident to front seat occupants for aeroplanes with and without shoulder harnesses. Then, they estimated the number of serious injuries which shoulder harnesses prevented for all occupants by subtracting the rates with and without shoulder harnesses. This difference reflects the number of serious injuries prevented for front seat occupants only, not all occupants. However, costs are included in the analysis for installing shoulder harnesses in all seats. Since the average number of seats in the small aeroplanes considered in the U.S. study was 4.05, the cost of retrofitting shoulder harnesses would be reduced by half if only front seat retrofit was evaluated. Thus, the cost-benefit ratio for front seat retrofit is twice the value given by Pailen-Johnston, i.e. 0.17.

Another factor very different in the Canadian and U.S. analyses is the accident rate per aeroplane. The rate used by Pailen-Johnston for the U.S. is much less than the rate for small Canadian commercial aeroplanes. The U.S. study considered both commercial and general aviation aeroplanes and, as the hours flown per year is less for general aviation aeroplanes, the accident rate per aeroplane would be expected to be less in the U.S. study. In addition, the costs of shoulder harness retrofit and value of injury and fatality reductions were different in the two studies. The values of various parameters used in the cost-benefit analysis by Pailen-Johnston and this study are compared in Table 9.7.

The cost-benefit analysis for retrofit of small commercial aeroplanes in Canada was rerun using the U.S. parameters given in Table 9.7 and a cost-benefit ratio of 0.18 was obtained. This compares with the value for the U.S., adjusted for front seat shoulder harnesses as discussed above, of 0.17. Thus, the different parameter values and the incorrect estimation of benefits in the U.S. study explain the difference between the cost-benefit ratios.

The U.S. cost-benefit ratio is greatly affected by the use of zero benefits for fatal injury reduction. If the injury rates with and without a shoulder harness from the Canadian accident data were used, allowing for only 40% of front seat occupants wearing them (U.S. usage rate), a cost-benefit ratio of 3.1 is obtained. Had the NTSB results on the effectiveness of shoulder harnesses been used, the cost-benefit ratio for installation of shoulder harnesses in the front seats should be close to this value of 3.1.

Table 9.9 Comparison of Parameters Used in the Cost-Benefit Analysis

Parameter	U.S.	Canada
Value of fatality	$650,000 (1986 US)	$2,500,000 (1989)
serious injury	$ 48,000 (1986 US)	$ 660,000 (1989)
minor injury	$ 0	$ 3,000 (1989)
Average installation cost per SH	$352 (1986 US)	$800 (1989)
Discount rate	10%	5% and 10%
Accident probability	0.0105 per year	0.0268 per year
Probability given accident and current SH usage:		
No fatality with SH	0.167 (0.26)#	0.102 (0.077)*
no SH	0.167 (0.26)#	0.142
Serious injury with SH	0.0687 (0.1072)#	0.067 (0.042)*
no SH	0.0881 (0.1375)#	0.091
Current SH usage rates when available	0.40**	0.70

SH Denotes shoulder harness.
* Assuming 100% usage.
\# Value given by Pailen-Johnston which is rate given an average of 1.56 occupants in front seats.
** For front seat occupants found in NTSB study [1].

The U.S. values of injury prevention are considerably lower than the values used in the Canadian analysis. Using the U.S. values, converted to 1989 Canadian dollars (based on an exchange rate of 85% and 4% inflation per year), the cost-benefit ratio was found to be 7 (for 10% discount rate and current shoulder harness usage).

9.6 Conclusions

The following conclusions can be reached from the results of the cost-benefit analysis for aeroplanes:

. 80% of small commercial aeroplanes in Canada did not require shoulder harnesses to be installed in the pilot and co-pilot seats when manufactured.

- Roughly 40% of small commercial aeroplanes in Canada not requiring shoulder harnesses when built have subsequently had shoulder harnesses installed. Thus, half of all small commercial aeroplanes currently have shoulder harnesses installed in the pilot and co-pilot seats.

- About 2,000 small commercial aeroplanes and 450 commercial helicopter currently do not have shoulder harnesses installed.

- The average shoulder harness retrofit cost for aircraft types in Canada is about $2,160 per aeroplane and $3,750 per helicopter.

- The retrofitting of shoulder harnesses in the pilot and co-pilot seats of all small commercial aeroplanes and commercial helicopters presently without them will prevent about 110 fatalities and 50 serious injuries over the life span of those aircraft.

- The retrofitting of shoulder harnesses is highly cost effective with benefits outweighing costs by a factor (cost-benefit ratios) varying between 8 and 100 for small commercial aeroplanes, and 5 to 40 for commercial helicopters, depending on the parameters used. Using the medium values of injury prevention, a 10% discount rate and the best estimates of injury reduction probabilities, the benefits are 23 times greater than the costs for aeroplanes and 13 times greater for helicopters.

- The retrofitting of shoulder harnesses is cost effective even for old aircraft provided they will be used for several more years at typical utilization rates.

- The benefits of shoulder harness installation would increase by 65% for small commercial aeroplanes and 27% for commercial helicopters if the usage rate increased from the present value to 100%.

- The large difference in the cost-benefit ratio for small aeroplanes found in the U.S. study (0.085) and in the present study (23) can be explained by the following (the size of the effect is given in brackets):

  (a) the use of zero benefits from fatality reduction due to shoulder harness in the U.S. study (factor of 7.3),
  (b) the lower value of life and injury prevention in the U.S. (factor of 7.9),
  (c) the higher accident rate per small aeroplane in Canada (factor of 2.6),

(d) the incorrect calculation of benefits of shoulder harnesses in the U.S. study (factor of 2.0),
(e) the lower usage rate of shoulder harnesses in the U.S. (factor of 1.8).
(f) the higher cost of shoulder harness retrofit in Canada (factor of 0.45).

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 It was concluded that:

- Canadian shoulder harness regulation is less advanced than that of the U.S. and Australia for small commercial aircraft.
- Approximately fifty percent of small commercial aircraft front seats are not fitted with shoulder harness.
- Approximately twenty five percent of shoulder harnesses are not used in aircraft in which they are fitted.
- The percentage of pilots killed wearing a shoulder harness is half that of pilots not wearing a shoulder harness in small aircraft.
- Injuries are considerably lower for pilots wearing shoulder harnesses in small aircraft.
- Approximately 38 fatalities and 64 serious injuries could have been prevented had all pilots of small commercial aircraft worn shoulder harness since 1976 in Canada.
- About 85% of small commercial aircraft have shoulder harness kits available from the original aircraft manufacturer or distributors and overhaul shops.
- The average cost for fitting the front seats of aeroplanes is $2,160 and $3,750 for helicopters.
- The retrofitting of shoulder harnesses in the front seats of helicopters and small commercial aeroplanes will prevent approximately 110 fatalities and 50 serious injuries over the life span of these aircraft.
- The cost-benefit ratio of 20 warrants the retrofitting of all helicopters and small commercial aeroplanes.
- The estimation of lead time to retrofit all front seats of small commercial aircraft with shoulder harnesses is impracticable because of the lack of certainty of the availability of kits, parts, and the conditions of aircraft seats, support structure and lap-belts.

10.2 It is recommended that:

- All helicopters and small commercial aeroplanes be retrofitted with front seat shoulder harnesses where such equipment is not now fitted.

- The effective date for fitment be established after consultation with the commercial operators, or within 5 years if no agreement is reached.

- Wearing of shoulder harness when available should be made mandatory for the front seat occupants during take-off and landing.

- Inertia reels should not be required if the pilot can reach essential controls and equipment with shoulder harness fastened.

REFERENCES

1. National Transportation Safety Board (NTSB). Discussed in: SYPHER:MUELLER, Small Aircraft Crashworthiness, Vol. 1. Report prepared for Transportation Development Centre, July 1987. TP8655E

2. Pailen-Johnston. Retrofit of Shoulder Harnesses in General Aviation Aircraft. Report prepared for FAA, Washington D.C. August 1986.

3. COPA. Human Behavior: The #1 Cause of Accidents. Flight Safety Bulletin No. 260, September 1989.

4. SYPHER:MUELLER. Evaluation of the Contribution of Aviation Safety Regulation and Aviation Safety Programs to Aviation Safety in Canada. Report prepared for Transport Canada, December 1989.

5. Statistics Canada. Canadian Civil Aviation. Yearly publication, catalog 51-206, 1983 to 1987.

6. SYPHER:MUELLER. Crash Firefighting and Rescue Services in Canada, Vol. II. Report prepared for Transport Canada, December 1988.

7. Canadian Aviation Safety Board. Study of the Influence of Shoulder Harnesses in Aviation Safety. CASB Report No. 87-SP0002, 1987.

APPENDIX A

SHOULDER HARNESS RETROFIT COSTS FOR EACH AIRCRAFT

Table 1. Cessna Aircraft In Canada *

No	A/C Model	Price	Installation Hours/Costs		Availability Manuf./Other		Total	Remarks
1	C140	298.80[1]	24	1248.00	yes[2]		1546.80	
"	"	299.05[3]	4	208.00		yes	407.05	
255	C150	541.80	8[4]	416.00	"	"	957.80	2>1978
219	C152	"			"	"		44-1978
								104>1978
7	C170	660.60[5]	8	"	"	"	1076.60	
"		255.60	"	"	"	"	671.60	
515	C172	"	"	"	"	"	"	43-1978
								136>1978
27	C72R	"	"	"	"	"	"	2-1978
								21 >1978
3	C175	"	"	"	"	"	"	
14	C177	367.20	"	"	"	"	783.20	
4	C77R	"	"	"	"	"	"	
117	C180	255.60	"	"	"	"	671.60	1-1978
								3>1978
44	C182	"	"	"	"	"	"	4-1978
								3>1978
	"	604.80	"	"	"		1020.80	note 5.
7	C82R	255.60	"	"	"	"	671.60	6-1978
296	C185	"	"	"	"	"	"	21-1978
								71 >1978
91	C188	N/A						Instal.[6]
155	C206	255.60	8	416	yes	yes	671.60	8-1978
								48>1978
26	C207	"	"	"	"	"	"	1-1978
								11 >1978

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1 Information for single engine CESSNA models is provided by ORILLIA AVIATION LIMITED, Lake St. John Airport, Orillia, Ontario.

2 Cessna Service Newsletter SNL 85-18 Revision 1 dated July 5, 1985; Title: SHOULDER HARNESS KIT AVAILABILITY For Single Engine and Skymaster Aircraft.

3 Generic shoulder harness for Cessna models 120 to 210 incl., no inertial reel. There is an STC number for this shoulder harness produced by WAG Aero.

4 It is assumed the shoulder harness structure is already installed in the aircraft. If the structure is not installed as in older models, then the installation time is 24 hours. Man/hours estimates for installation is provided by INNOTECH Aviation Enterprises Ltd., Montreal International Airport.

5 Four harnesses per kits. Only the two front seats installed for the estimate of man/hours.

6 Aircraft manufactured with shoulder harness - RETROFIT OF SHOULDER HARNESS IN GENERAL AVIATION AIRCRAFT, FINAL REPORT, August 20, 1986. Pailen-Johnson Associates, Inc.

* Costs are for retrofitting of shoulder harness in both front seats

No	A/C Model	Price	Installation Hours/Costs	Availability Manuf./Other	Total	Remarks
8	C208	N/A				ALL>1978
11	C210	565.20	" "	" "	981.20	1-1978
	"	1137.60	" "	"	1553.60	1>1978
	"	583.20	" "	"	999.20	
	"	338.40	" "	"	754.40	
	"	no quote		"		others
3	C305	N/A				ex. mil. L19
59	C310	354.60[7]	"	" no[8]	770.60	2-1978 6>1978
2	C320	"	" "	"	"	notes 7&8
3	C335	N/A				ALL>1978
2	C336	no quote[9]		"		
46	C337	421.20'	" "	"	837.20	2-1978 1>1978
14	C401	354.60	" "	"	770.60	notes 7&8
47	C402	"	" "	" "	"	7-1978 15>1978
8	C404	N/A				Instal. note 6.
3	C411	354.60	" "	"	"	notes 7&8
15	C414	"	" "	" "	"	2>1978
21	C421	"	" "	"	"	notes 7&8 2>1978
2	C425	N/A				ALL>1978
8	C441	N/A				Instal. note 6.
27	C500	354.60	" "	"	"	notes 7&8 3-1978
2	C501	N/A				ALL>1978
2062	34					

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7 Estimated by Cessna Customer Support, Wichita, Kansas. Exact price and availability of shoulder harnesses cannot be verified without part numbers.

8 There is no kit available as such. However, all the parts to satisfy the requirement may be ordered. Shoulder harness stocks for older models twins may be depleted, as well as stocks for short run aircraft production. In those cases, shoulder harnesses are made to order and are very expensive.

9 Made to order only.

Table 2. Beech Aircraft In Canada *

No	A/C Model	Price	Installation Hours/Costs		Availability Manuf./Other	Total	Remarks
4	BE11				no[1]		
1	BE17				"		
17	BE18				"		
18	BE8S				"		
8	BE8T				"		
18	BE23	2228.00[2]	17[3]	884.00	yes[4]	3112.00	4-1978
						6>1978	
21	B23R	"	"	"	"	"	2 -1978
1	BE45	N/A					ex. USAF
17	BE55	1984.00	"	"	yes	3232.00	1>1978
		2011.00	"	"	"	3259.00	
		1883.00	"	"	"	3131.00	
		2448.00	"	"	"	3696.00	
		1895.00	"	"	"	3143.00	
		2089.00	"	"	"	3337.00	
		1499.00	"	"	"	2747.00	
		1790.00	"	"	"	3038.00	
7	BE56	1984.00	"	"	"	3232.00	1-1978
		2011.00	"	"	"	3259.00	2>1978
3	BE60	2325.00	"	"	"	3573.00	
13	BE65	1155.00	30	1560.00	"	2715.00	
9	BE76	N/A					Instal.[5]
2	BE80	1155.00	30	1560.00	yes	2715.00	
8	BE90	1155.00	"	"	"	"	

1 None advertised in Beechcraft Service Bulletin No. 2031 ATA Code 25-00 Issued June, 1985; Title: EQUIPMENT FURNISHINGS - NOTICE OF AVAILABILITY OF SHOULDER HARNESS KITS.

2 Information on cost of acquisition of shoulder harness kits for all Beech models is provided by Field Aviation Parts Sales Ltd., Hangar 3, 2450 Derry Rd. E, Mississauga, Ontario, L5S 1B2.

3 Man hours as per Beechcraft Mandatory Service Bulletin No. 2031 ATA Code 25-00 Issued June, 1985; Title: EQUIPMENT FURNISHINGS - NOTICE OF AVAILABILITY OF SHOULDER HARNESS KITS.

4 Availability as per Beechcraft Mandatory Service Bulletin No. 2031 ATA Code 25-00 Issued June, 1985; Title: EQUIPMENT FURNISHINGS - NOTICE OF AVAILABILITY OF SHOULDER HARNESS KITS.

5 Aircraft manufactured with shoulder harness - RETROFIT OF SHOULDER HARNESS IN GENERAL AVIATION AIRCRAFT, FINAL REPORT, August 20, 1986. Pallen-Johnson Associates, Inc.

* Costs are for retrofitting of shoulder harness in both front seats

No	A/C Model	Price	Installation Hours/Costs		Availability Manuf./Other	Total	Remarks
15	BE95	1499.00 1790.00	24 "	1248.00 "	" "	2747.00 3038.00	
22	BE99	1155.00	30	1560.00	"	2715.00	2>1978
27	BE10	1155.00	"	"	"	"	1>1978
7	BE20	N/A					ALL >1978

218	19						

Table 3. Piper Aircraft in Canada*

No	A/C Model	Price	Installation Hours/Costs		Availability Manuf./Other		Total	Remarks
8	PA6				no			
1	PA11	659.56[1]	8	416.00	no	yes	1075.56	
14	PA12				"			
1	PA14				"			
1	PA16				"			
44	PA18				"			1-1978 4>1978
1	PA20				"			
6	PA22				"			
138	PA23				"			1-1978 4>1978
4	PA24	848.68[2]	8	"	no	yes	1264.68	
	"	933.78	"	"	"	"	1349.78	
80	PA25	N/A						Instal.[3]
142	PA28	363.96	8[4]	"	yes		779.96	8 1978 18>1978
	"	N/A						Instal.[5]
20	PA30	848.68	8	"	no	yes	1264.68	note 2.
152	PA31				"			
44	PA3T				no			7-1978 23>1978
80	PA32	333.70	8	416.00	yes		749.70	note 4. 18-1978 55>1978
	"	N/A						Instal.[6]
3	P32R	N/A						Instal.[7]

1 Shoulder Harness produced by Kosola and Associates, Inc. Aeronautical Engineers, 5601 Newton Road, Albany, Georgia, U.S.A. 31706. STC SA 2057SO FAA/PMA approved.

2 Shoulder Harness produced by Kosola and Associates, Inc. Aeronautical Engineers, 5601 Newton Road, Albany, Georgia, U.S.A. 31706. STC SA 1689SO FAA/PMA approved.

3 Aircraft manufactured with shoulder harness - RETROFIT OF SHOULDER HARNESS IN GENERAL AVIATION AIRCRAFT, FINAL REPORT, August 20, 1986. Pallen-Johnson Associates, Inc.

4 It is assumed the shoulder harness structure is already installed in the aircraft. If the structure is not installed as in older models, then the installation time is 24 hours. Man/hours estimates for installation is provided by INNOTECH Aviation Enterprises Ltd., Montreal International Airport.

5 Some PA28 series have been manufactured with shoulder harness installed as standard equipment. Piper Aircraft Service Bulletin No. 896 dated november 28, 1988.

6 Some PA32 series have been manufactured with shoulder harness installed as standard equipment. Piper Aircraft Service Bulletin No. 896 dated november 28, 1988.

7 All P32R, PA44 and PA46 series have been manufactured with shoulder harness installed as standard equipment. Piper Aircraft Service Bulletin No. 896 dated november 28, 1988.

* Costs are for retrofitting of shoulder harness in both front seats

No	A/C Model	Price	Installation Hours/Costs	Availability Manuf./Other	Total	Remarks
1	PA34	333.70	" "	yes	"	note 4.
	"	N/A				1-1978 Instal.[8]
15	PA36	N/A				Instal. note 3.
3	PA38	N/A				"
10	PA42	N/A				"
19	PA44	N/A				Instal. note 7.
1	PA46	N/A				"
70	PA60	N/A				Instal. note 3.

858	24					

8 PA34 series 34-8133001 and up have been produced with shoulder harness as standard equipment. Piper Aircraft Service Bulletin No. 896 dated november 28, 1988.

Table 4. Rockwell International Aircraft in Canada *

No	A/C Model	Price	Installation Hours/Costs	Availability Manuf./Other	Total	Remarks
3	AC2A	N/A				Instal.[1]
1	AC6	N/A				"
37	AC6A	N/A				"
11	AC50			no		
6	AC60			"		
8	AC68			"		
3	AC69	unk.		yes[2]		2>1978

69	7					

Table 5. Dehavilland Aircraft in Canada *

No	A/C Model	Price	Installation Hours/Costs		Availability Manuf.c/Other	Total	Remarks
3	DH82				no		
309	DHC2	4142.52[3]	12	624.00	yes	4766.52	
118	DHC3				no		
83	DH6	2500.00[4]	20	1040.00	yes	3540.00	4-1978

513	4						

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1 Aircraft manufactured with shoulder harness - RETROFIT OF SHOULDER HARNESS IN GENERAL AVIATION AIRCRAFT, FINAL REPORT, August 20, 1986. Pallen-Johnson Associates, Inc.

2 Custom kits available for models 690 As and Bs.

3 Information is provided by Viking Air Ltd., Victoria International Airport, Sidney, B.C.

4 De Havilland Service Bulletin No. 6/158 Revision "A", February 21, 1975; Title: Shoulder Harness and Inertia Reel - "Teleflex" or "Pacific Scientific" Type - S.O.O. 6014. The 1975 price quoted is 1821.33$; the 2500.00$ price quoted is an estimate from a DeHavilland Customer Support Official.

* Costs are for retrofitting of shoulder harness in both front seats

Table 6. Gulfstream American Aviation Aircraft in Canada *

No	A/C Model	Price	Installation Hours/Costs	Availability Manuf./Other	Total	Remarks
1	AA1					
3	AA5					
6	GA7	N/A		None[1]		4-1978
						2>1978
10	G21			"		
75	G164	N/A				Instal.[2]

95	5					

Table 7. Pilatus Britten Norman Aircraft in Canada *

No	A/C Model	Price	Installation Hours/Costs		Availability Manuf./Other	Total	Remarks
36	BN2	160.00[3]	2	104.00	yes	264.00	1-1978
1	BN3	"	"	"	"	"	
2	PL6A	"	"	"	"	"	

39	3						

---

1 nformation provided by Viking Air Ltd., Victoria International Airport, Sidney, British Colombia.

2 Aircraft manufactured with shoulder harness - RETROFIT OF SHOULDER HARNESS IN GENERAL AVIATION AIRCRAFT, FINAL REPORT, August 20, 1986. Pallen-Johnson Associates, Inc.

3 Information provided by HIGH-LINE AVIATION LID., Bramalea, Ontario. The kit provided by the aircraft manufacturer is a diagonal sash type, forming an X across the chest. There is no inertial reel.

* Costs are for retrofitting of shoulder harness in both front seats

Table 8. Helicopter Aircraft in Canada *

No	A/C Model	Price	Installation Hours/Costs		Availability Manuf./Other		Total	Remarks
	Bell							
63	BH04	N/A						instal.[1]
541	BH06	3664.20[2]	30[3]	1560.00	yes		5224.20	note[4]
	"	2830.89[5]				yes		
39	BH12	N/A						note 1.
2	BH22	N/A						"
1	B412	N/A						"
71	BH47	6973.80			yes[6]			
	Sikorsky							
9	SK55	N/A						instal.[7]
1	SK58	N/A						instal.[8]
13	SK76	N/A						note 8.
	Aerospatiale							
2	S316	1790.60[9]			yes			
3	S318	"			"			
75	S350	4435.34	6[10]	312.00	yes		4747.34	
9	S355	3315.77	6	312.00	"		3627.77	
10	S341	No quote			no			
	Hughes							
33	HU30	1778.93[11]	2	104.00	yes		1882.93	
92	HU50	2641.11	"	"	"		2641.11	note[12]
	Enstrom							
8	EN28							
	Hiller Aircraft Corporation							
11	HH12							
	Robinson Helicopter							
22	H22							
	Messerschmitt							
2	MB05	N/A						instal.[13]
2	MB17	N/A						"

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1 All aircraft manufactured with shoulder harnesses. Confirmed by Bell Helicopter's Chief Flight Safety Engineer, Forth Worth, Texas.

2 Information provided by Bell Helicopter, Forth Worth, Texas, U.S.A.

3 Man/hours estimate provided by AOG Heliservices Inc., Kingston, Ontario.

4 All aircraft manufactured after January 1981 were equipped with shoulder harnesses as standard equipment.

5 Information provided by Aeronautical Accessories, Tennesse.

6 There are no kits available for J series BH47s.

7 California Helicopters representative confirmed all SK55 manufactured with shoulder harnesses with inertial reel.

8 Sikorsky Aircraft customer support representative confirmed all SK58 and SK76 models were manufactured with shoulder harnesses.

9 Information provided by AEROSPATIALE Helicopter Corp., Lachine, Qubec.

10 Man/hours estimate provided by Viking Helicopters Ltd., Les Cdres, Qubec.

11 Information on price and estimate of installation is provided by HELIMAX, Trois-Rivires, Qubec.

12 The Hughes 500E models and after were produced with shoulder harnesses for the pilot seat only as standard equipment. Centre seats and passengers seats may be equipped with a belt across the chest such as in automobiles.

13 Information provided by MBB test pilot.

* Costs are for retrofitting of shoulder harness in both front seats

No	A/C Type	Price	Installation Hours/Costs	Availability Manuf./Other	Total	Remarks
	Sud Aviation					
3	SE18					318 Sud aviation
	Summa Corporation					
8	S69					369 Summa
	Fairchild Hiller					
6	FH11					FH-1100 Fairchild
	Brantly Helicopter					
1	HB42					Brantly

1027	25					

Table 9. Miscellaneous Aircraft in Canada*

No	A/C Type	Price	Installation Hours/Costs	Availability Manuf./Other	Total	Remarks
	Aeronca MFG					
3	AR11					
1	AR15					
8	AR58					
	Avions de Transport Regional					
4	AT30	N/A				ALL > 1978
1	AT40	N/A				ALL > 1978
	Boeing Company					
7	B75					
	Bellanca Miller					
2	BL28	N/A				instal.[1]
6	BL30	N/A				*
1	BL66					
	Callair Imco					
1	CA1					
	Champion Aircraft Corp.					
20	CH7					
	Dornier Werke					
1	DO28					
	PZL Mielic Poland					
12	DROM	N/A				instal.
2	POW4					note 1.
	Embraer					
6	E110					
	Helio					
4	E391					
5	E395					
	Fairchild Industries					
4	FA24					
20	SW2					2-1978
9	SW4					
	Found Brothers					
5	FB2					
	Fleet					
3	FL80					
	Hawker Siddeley					
1	HS04					
	Colonial Lake Aircraft					
2	LC4	N/A				instal. note 1.
	Maule					
2	ML6	N/A				ALL > 1978
5	MU4					2-1978
	Mooney Aircraft					
1	MO20					

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1 Aircraft manufactured with shoulder harness - RETROFIT OF SHOULDER HARNESS IN GENERAL AVIATION AIRCRAFT, FINAL REPORT, August 20, 1986. Pallen-Johnson Associates, Inc.

* Costs are for retrofitting of shoulder harness in both front seats

No	A/C Type	Price	Installation Hours/Costs	Availability Manuf./Other	Total	Remarks
	Mitsubishi					
10	MU2					1-1978
	North American					
1	NAT6	N/A				ex. mil. Harvard
	Noorduya					
4	NO4					
21	NO5					
13	NO6					
	Pilatus Aircraft					
1	P68C					
	Stinson					
1	ST10					
23	ST75					7-1978 10>1978
	Temco Aircraft					
3	TE11					1-1978
	Ted Smith Aircraft Co.					
8	TS60					
	Universal Globe					
1	WACO					

222	38					

APPENDIX B

TABLES OF ACCIDENTS BY SHOULDER HARNESS USAGE AND PILOT INJURY

The following tables of the number of injuries to pilots of helicopters, and small commercial aeroplanes involved in accidents during the period 1976 to September, 1989 were extracted from the ASIS database.

1. SMALL COMMERCIAL AEROPLANES

Injury to Pilot	Pilot Shoulder Harness: Installed Not Used		Installed Used		Not Used	
No Injury	147	(58.8%)	458	(79.8%)	640	(65.7%)
Minor Injury	32	(12.8%)	48	(8.4%)	94	(9.7%)
Serious Injury	31	(12.4%)	24	(4.2%)	97	(10.0%)
Fatal:						
Survivable Acc.*	17	(6.8%)	6	(1.1%)	43	(4.4%)
Non-survivable Acc.	23	(9.2%)	38	(6.6%)	100	(10.3%)
Total Fatal	40	(16.0%)	44	(7.7%)	143	(14.7%)
Total Accidents	250	(100%)	574	(100%)	974	(100%)

Injury to Pilot	Pilot Shoulder Harness: Installed		Not Installed		Total	
No Injury	605	(73.4%)	493	(68.1%)	1098	(70.9%)
Minor Injury	80	(9.7%)	62	(8.6%)	142	(9.2%)
Serious Injury	55	(6.7%)	66	(9.1%)	121	(7.8%)
Fatal:						
Survivable Acc.*	23	(2.8%)	26	(3.6%)	49	(3.2%)
Non-survivable Acc.	61	(7.4%)	77	(10.6%)	138	(8.9%)
Total Fatal	84	(10.2%)	103	(14.2%)	187	(12.0%)
Total Accidents	824	(100%)	724	(100%)	1548	(100%)

2. HELICOPTERS

Injury to Pilot	Pilot Shoulder Harness: Installed Not Used		Installed Used		Not Used	
No Injury	37	(60.7%)	184	(65.2%)	202	(61.0%)
Minor Injury	6	(9.8%)	46	(16.3%)	37	(11.2%)
Serious Injury	8	(13.1%)	36	(12.8%)	44	(13.3%)
Fatal:						
Survivable Acc.*	3	(4.9%)	3	(1.1%)	11	(3.3%)
Non-survivable Acc.	7	(11.5%)	13	(4.6%)	37	(11.2%)
Total Fatal	10	(16.4%)	16	(5.7%)	48	(14.5%)
Total Accidents	61	(100%)	282	(100%)	331	(100%)

Injury to Pilot	Pilot Shoulder Harness: Installed		Not Installed		Total	
No Injury	221	(64.4%)	165	(61.1%)	386	(63.0%)
Minor Injury	52	(15.2%)	31	(11.5%)	83	(13.5%)
Serious Injury	44	(12.8%)	36	(13.3%)	80	(13.1%)
Fatal:						
Survivable Acc.*	6	(1.7%)	8	(3.0%)	14	(2.3%)
Non-survivable Acc.	20	(5.8%)	30	(11.1%)	50	(8.2%)
Total Fatal	26	(7.6%)	38	(14.1%)	64	(10.4%)
Total Accidents	343	(100%)	270	(100%)	613	(100%)

* Includes accidents classified as survivable and partly survivable by the CASB.

APPENDIX C

ISOLATING THE EFFECT OF SHOULDER HARNESS USAGE

Evaluate shoulder harness effectiveness by comparing the injury rates when a shoulder harness was used and when it was not used because it was not installed (i.e., the pilot would have worn it had it been installed). This can be done by comparing the probabilities:

$$P(I=f \mid A=y,W=y) \quad \text{and} \quad P(I=f \mid A=n,W=y)$$

where I is the injury (f=fatal, s=serious, m=minor, n=none),
A is the availability of shoulder harness (y=yes, n=no),
W is the willingness of pilot to use shoulder harness (y=yes, n=no).

From the accident data (see Appendix B),

$$P(I=f \mid A=y,W=y) = 0.077 \qquad (1)$$
$$P(I=f \mid A=y,W=n) = 0.160 \qquad (2)$$
$$P(W=y) = 0.70 \qquad (3)$$

Let the probability that a pilot will wear a shoulder harness if it is available be given by

$$P(W=y \mid A=y) = p_w$$

Now,

$$P(I=f \mid A=n,W=y) = P(I=f,W=y \mid A=n) \,/\, P(W=y \mid A=n)$$
$$= P(I=f,W=y \mid A=n) \,/\, p_w$$

$$\Rightarrow \quad P(I=f,W=y \mid A=n) = p_w \, P(I=f \mid A=n,W=y) \qquad (4)$$

Similarly,

$$P(I=f \mid A=n,W=n) = P(I=f,W=n \mid A=n) \,/\, P(W=n \mid A=n)$$
$$= P(I=f,W=n \mid A=n) \,/\, (1 - p_w)$$

$$\Rightarrow \quad P(I=f,W=n \mid A=n) = (1 - p_w) \, P(I=f \mid A=n,W=n) \qquad (5)$$

Summing equations (4) and (5) (noting that W can only take values of "y" or "n") gives:

$$P(I=f \mid A=n) = p_w \, P(I=f \mid A=n,W=y) + (1 - p_w) \, P(I=f \mid A=n,W=n)$$

$$\Rightarrow \quad P(I=f \mid A=n,W=y) = \{\, 0.141 - (1 - p_w) \, P(I=f \mid A=n,W=n) \,\}/p_w$$

If the pilot is unwilling to wear a shoulder harness, the probability of injury is the same whether the shoulder harness is installed or not installed as the pilot will not be wearing it in either case. Thus, from equation (2),

$$P(I=f \mid A=n,W=n) = P(I=f \mid A=y,W=n) = 0.160$$

Thus,

$$P(I=f \mid A=n,W=y) = (0.141 - (1 - p_w) \times 01.60)/p_w \quad (6)$$

If it is assumed that the willingness of a pilot to wear a shoulder harness is independent of its availability, then from equation (3) $p_w = 0.7$ and

$$P(I=f \mid A=n,W=y) = 0.133$$

This compares to the fatality rate of 0.077 when the shoulder harness is available and the pilot is willing to wear it. The independence assumption is unlikely to hold as pilots willing to wear shoulder harnesses are more likely to ensure the aeroplane they fly have shoulder harnesses available. However, the probability given in equation (6) is not very sensitive to the independence assumption for values of p_w near 0.7. Even when $p_w = 0.5$, the probability of being fatally injured when a shoulder harness is not available but the pilot is willing to wear one is 0.122.

Thus, shoulder harnesses reduce the fatality rate by about 40% after allowing for the effect of a pilot's willingness to wear a shoulder harness on the accident severity.

APPENDIX D

EXAMPLES OF ASSIGNMENT OF INJURY PROBABILITIES HAD SHOULDER HARNESSES BEEN USED

Part of the analysis of the benefits of shoulder harnesses involved the assigning to probabilities of a pilot receiving particular injuries had they been wearing shoulder harnesses. As described in Section 7.3, a number of factors given in the accident report summaries were taken into consideration when assigning these probabilities. Four examples are given below of the processes and important factors used in coming up with probabilities of injury had a shoulder harness been used. The CASB accident report summaries for the four accidents are also given.

Example 1: Cessna 172 on 23/12/86

The pilot received serious injuries. He was wearing a seat belt, which held, but not a shoulder harness.

The impact speed was relatively low, 40 kt, and the impact angle not given, but from narrative angle was not steep. The crash was well within survivability envelop. The impact damage to the cabin was only moderate. No other people were in the aircraft to compare injuries with. The aircraft slid for 80 feet after impact and did not strike any obstacles. From this it was concluded that the pilot's injuries would almost certainly have been less severe had he been wearing a shoulder harness. Some minor injury was still quite likely as the aircraft struck the ground with one wing tip then the other before coming to rest on a broken nose wheel which may have produced some uncontrolled movements of the limbs during the accident. Rescue assistance was available within a short time period and environmental effects and terrain did not affect injuries after the crash.

The assigned probabilities of injury had he been wearing a shoulder harness were:

Serious	0.05
Minor	0.65
None	0.30

Example 2: Cessna 172 on 14/05/77

The pilot was seriously injured in the crash. He was wearing a seat belt, but not a shoulder harness.

The impact speed was relatively low, 40 kt, but the impact angle was steep, 45 degrees. The crash was well within the survivability envelope indicating that the "G" forces were not severe. The impact damage was only moderate indicating that intrusion of the aircraft frame into the liveable area was unlikely. However, one passenger was killed and two others

were seriously injured. The aircraft cartwheeled after it struck the ground and this was likely the reason for the severity of the injuries. A shoulder harness would be effective in preventing injuries in these situations. Rescue assistance was available within five minutes and environmental effects and terrain did not affect injuries after the crash. Thus, despite the injuries to others aboard who were also not wearing shoulder harnesses, it was concluded that the pilot was fairly likely to have reduced injuries had he been wearing a shoulder harness. Some minor injury was still very likely as the aircraft cartwheeled when it struck the ground and there would have been some uncontrolled movement of the limbs during the accident.

The assigned probabilities of injury had he been wearing a shoulder harness were:

Serious	0.40
Minor	0.50
None	0.10

Example 3: Cessna 172 on 09/06/76

The pilot was killed in the accident. He was wearing a seat belt, but not a shoulder harness.

The impact speed was not high, 50 kt, but the impact angle was steep, 40 degrees. The crash was within, but fairly close to the edge of, the survivability envelope indicating that the "G" forces were considerable, but not severe. The impact damage was severe indicating that some intrusion of the aircraft frame into the liveable area was likely. Both passengers survived, but received serious injuries. Rescue assistance was available within a minute and environmental effects and terrain did not affect injuries after the crash. It was therefore concluded that a shoulder harness would have very likely saved the pilots life, but that he would most likely have still received serious injuries. The assigned probabilities of injury had he been wearing a shoulder harness were:

Fatal	0.15
Serious	0.60
Minor	0.25
None	0.0

Example 4: Cessna 172 on 24/04/77

The pilot was killed in the accident. He was wearing a seat belt which failed, but not a shoulder harness.

The impact speed was very high, 110 kt and the impact angle was relatively steep for that speed, 20 degrees. The crash was well outside of the survivability envelope indicating that the "G" forces were very severe. The impact damage to the cockpit was extreme indicating that there was almost certainly some intrusion of the aircraft frame into the liveable area of the pilot. Two passengers were killed and one survived. Rescue assistance was available within a short time period and environmental effects and terrain did not affect injuries after the crash. It was therefore concluded that a shoulder harness would most likely have not save the pilots life and, it had done so, the pilot would have received serious injuries.

The assigned probabilities of injury had he been wearing a shoulder harness were:

Fatal	0.70
Serious	0.30
Minor	0.0
None	0.0

Example 1

```
+ ACCIDENT DATA REPORT:                    CESSNA - 172                              FILE 86-C60118 +   PAGE  3.
+ TYPE OF OCCURRENCE: 1)COLLISION LEVEL SURFACE-UNCONTROLLED 2)COLLISION LEVEL SURFACE-UNCONTROLLED    +  PRINTED
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++31 OCT  89

<-------------------- REPORT IDENTIFICATION ---------------------> ++ <---------------------- INJURIES TO PERSONS ----------------------;
                                                                   ++
*FROM REGION          : CENTRAL                                    ++ *INJURY INDEX         : SERIOUS
*FILE NUMBER          : C60118                                     ++
*REPORT SUBMITTED     : 8 FEB 88                                   ++                                > > > > > NUMBER OF INJURIES < < < < <
                                                                   ++
 LAST RECORD CHANGE   : 12 JUNE 89                                 ++ PERSONNEL                FATAL SERIOUS MINOR  NONE UNKNOWN  TOTAL
                                                                   ++
<------------------- OCCURRENCE IDENTIFICATION -----------------> ++ *PILOT            :          1     .65    .30                1
                                                                   ++  TOTAL CREW       :          1     .65    .30                1
*A/C REGISTRATION     : C-GKYJ                                     ++
*STATE OF REGISTRY    : CANADA                                     ++  PASSENGERS       :                                       0
*DATE                 : 23 DEC 86                                  ++
*TIME                 : 12:30 LOCAL                                ++ *TOTAL ABOARD     :          1                            1
                                                                   ++
 LOCATION                                                          ++ *GRAND TOTAL      :          1                            1
* -NAME                : PICKLE LAKE                                ++
* -PROVINCE            : ONTARIO                                    ++
* -CATA REGION         : CENTRAL                                    ++ <------------------------------ DAMAGE ------------------------------;
* -LATITUDE            : 52 27 N                                    ++
* -LONGITUDE           : 090 14 W                                   ++ *DAMAGE TO AIRCRAFT : SUBSTANTIAL
* -STATE/AREA          : CANADA                                     ++
                                                                   ++
<-------------------- HISTORY OF THE FLIGHT ---------------------> ++ <---------------- WRECKAGE AND IMPACT INFORMATION ----------------;
                                                                   ++
*OPER'N GENERAL AV'N   : NONCOMMERCIAL/BUSINESS-NON.PROF. PILOT     ++  WRECKAGE RECOVERED : YES
 LOAD DESCRIPTION     : NONE                                       ++
 LOAD POSITION        : NONE                                       ++  TERRAIN
                                                                   ++   -TYPE            : LEVEL FLAT
*DEPARTED FROM        : SAME AS LOCATION                           ++   -SURFACE-GENERAL : HARD
*INTENDED LANDING AT  :  THUNDER BAY                               ++   -SURFACE-SPECIFIC: ICE
                                                                   ++
 DEPARTURE BRIEFING   : AIS NOT AVAILABLE                          ++  FIRST IMPACT
*FLIGHT PLAN/CLEARANCE: NO FLIGHT PLAN - NO CLEARANCE              ++   -ELEVATION       : 360 M (1181 FEET)
 TYPE OF FLIGHT PLAN  : NONE                                       ++
 DURATION OF FLIGHT   : 0 HRS 03 MIN                               ++  WRECKAGE TRAIL
 AIRSPACE SEGMENT     : UNCONTROLLED AIRSPACE                      ++   -LENGTH          : 46 M (151 FEET)
                                                                   ++
 PHASE OF OPERATION                                                ++ AIRCRAFT ATTITUDE     > > AT IMPACT < <      > > AT REST < <
* -FIRST               : TAKE-OFF INITIAL CLIMB                     ++
  -SECOND              : ENROUTE/EMERGENCY DESCENT                  ++   -ROLL            : 30 DEG LEFT ROLL     0 DEG WINGS LEVEL
                                                                   ++   -PITCH           : 0 DEG LEVEL          0 DEG LEVEL
 ALTIT. OF OCCURR.    : 152 M (499 FEET)                           ++   -YAW             : 0 DEG ZERO YAW       90 DEG RIGHT YAW
 SPEED AT IMPACT      : 40 KT                                      ++
                                                                   ++  AERODROME
 EMERGENCY CIRCUM.    : SUSPECTED/KNOWN MECHANICAL DEFECT          ++   -PROXIMITY       : WITHIN .8 KM
 FORCED LANDING       : OFF AERODROME ON LAND                      ++
 APPROACH FLOWN       : VISUAL APP (NO AIDS)-STRAIGHT IN           ++
 MILITARY INVOLVEMENT: NO                                          ++
                                                                   ++
                                                                   ++
                                                                   ++
                                                                   ++
```

SURVIVAL DATA

SURVIVABILITY	: SURVIVABLE
POST CRASH ESCAPE	: WITH DIFFICULTY
OCCUPANTS	
-EVACUATED	: 1
-NOT EVACUATED	: 0
FATALITIES	
-FROM BURNS	: 0
-FROM TOXIC FUMES	: 0
IMPACT DAMAGE	
-A/C WITH NO CABIN	: MODERATE
SEATS	
-CONFIGURATION	: FURWARD FACING
-OCCUPIED/FAILED	: 0
SEAT BELT	
-NUMBER FAILED	: 0
SHOULDER HARNESS	
-PILOT	: INSTALLED - NOT USED
PILOT'S SEAT BELT	: FASTENED LOOSELY
EVACUATION	
-MEANS OF EXIT	: MAIN DOOR, FORWARD
-TIME	: UNKNOWN
-ASSISTANCE	: NOT REQUIRED
-CHUTE/SLIDE	: NOT AVAILABLE
-ROPE	: NOT AVAILABLE
-LADDER	: NOT AVAILABLE
-EMERGENCY LIGHTS	: NOT AVAILABLE

NARRATIVE

AFTER TAKE-OFF FROM PICKLE LAKE AIRPORT, ONTARIO, FOR A VISUAL FLIGHT RULES FLIGHT TO THUNDER BAY, THE AIRCRAFT WAS OBSERVED ROCKING FROM SIDE TO SIDE, AND IT DESCENDED AND STRUCK THE FROZEN SURFACE OF PICKLE LAKE. THE NOSEWHEEL COLLAPSED, AND BOTH WINGS WERE DAMAGED BEFORE THE AIRCRAFT CAME TO REST.

THE HIGHLY EXPERIENCED PILOT FLYING THE RENTED AIRCRAFT REPORTED THAT THERE HAD BEEN A LOSS OF ENGINE POWER AFTER TAKE-OFF. HE STATED THAT HE APPLIED CARBURETTOR HEAT, AND THE ENGINE RESPONDED SLIGHTLY BUT CONTINUED TO SPUTTER UNTIL THE AIRCRAFT STRUCK THE LAKE SURFACE. INITIAL GROUND CONTACT WAS MADE WITH THE LEFT WING TIP. THE AIRCRAFT THEN ROLLED TO THE RIGHT, DAMAGING THE RIGHT WING TIP AND SHEARING OFF THE NOSE GEAR, BEFORE COMING TO REST ON ITS NOSE. THE TOTAL DISTANCE TRAVELLED ON THE GROUND WAS ABOUT 160 FEET.

NARRATIVE (CONTINUED)

AN EXAMINATION OF THE ENGINE REVEALED THAT ALL ENGINE SYSTEMS WERE SERVICEABLE. THE DAMAGE TO THE PROPELLER INDICATED THAT THE ENGINE WAS DEVELOPING POWER AT IMPACT. THE ENGINE CONTROLS WERE POSITIONED FOR TAKE-OFF POWER. THE AIRCRAFT CONTROL SYSTEMS FUNCTIONED NORMALLY.

THE PILOT LANDED AT PICKLE LAKE THE MORNING OF THE ACCIDENT AND SPENT ABOUT AN HOUR AND A HALF ON THE GROUND. DURING THIS TIME, HE TALKED TO SEVERAL PEOPLE AND WAS OBSERVED TO BE QUITE DRUNK. AT LEAST ONE WITNESS OBSERVED THE PILOT DRINKING STRAIGHT FROM A WHISKEY BOTTLE, AND THIS WITNESS WAS OFFERED A "CHRISTMAS" DRINK BY THE PILOT. FOLLOWING THE ACCIDENT, THE PILOT REFUSED TO GIVE BLOOD OR BREATH SAMPLES TO POLICE. THE POLICE BELIEVED THE PILOT TO BE DRUNK, AND HE WAS CHARGED WITH OPERATING AN AIRCRAFT WHILE HIS ABILITY WAS IMPAIRED BY ALCOHOL.

THE IMPACT MARKS INDICATED THAT THE AIRCRAFT STRUCK THE SURFACE OF THE LAKE WHILE OUT OF CONTROL AND WITH THE ENGINE OPERATING. THE PILOT LOST CONTROL OF THE AIRCRAFT BECAUSE HIS ABILITY WAS IMPAIRED BY ALCOHOL.

CONCLUSION:

FINDINGS:

1. THERE WAS NO EVIDENCE OF ANY AIRCRAFT MALFUNCTION.

2. THE AIRCRAFT WAS OUT OF CONTROL WHEN IT STRUCK THE LAKE SURFACE.

3. THE ABILITY OF THE PILOT TO OPERATE THE AIRCRAFT WAS IMPAIRED BY ALCOHOL.

CAUSES:

THE PILOT LOST CONTROL OF THE AIRCRAFT BECAUSE HIS ABILITY WAS IMPAIRED BY ALCOHOL.

FACTORS

<A> RELATED TO FIRST OR ONLY TYPE OF OCCURRENCE

01 PILOT:
INCAPACITATION
02 -SPECIFICALLY:
ALCOHOLIC IMPAIRMENT

Example 2

```
+ ACCIDENT DATA REPORT:                CESSNA - 172                    FILE 77-Q70042 +  PAGE  5
+ TYPE OF OCCURRENCE:    LOSS OF CONTROL IN FLIGHT/MUSH/STRAIGHT STALL                  +  PRINTED
                                                                                        31 OCT 89

<------------------- REPORT IDENTIFICATION ------------------->

*FROM REGION          : QUEBEC
*FILE NUMBER          : Q70042
*REPORT SUBMITTED     : 17 JAN 78

 LAST RECORD CHANGE   : 11 MAR 83

<------------------- OCCURRENCE IDENTIFICATION ----------------->

*A/C REGISTRATION     : C-GAFT
*STATE OF REGISTRY    : CANADA
*DATE                 : 14 MAY 77
*TIME                 : 09:05 LOCAL

 LOCATION
* -NAME               : STE THERESE A/P
* -PROVINCE           : QUEBEC
* -CATA REGION        : QUEBEC
* -LATITUDE           : 45 42 N
* -LONGITUDE          : 073 48 W
* -STATE/AREA         : CANADA

<------------------- HISTORY OF THE FLIGHT --------------------->

*OPER'N GENERAL AV'N  : NONCOMMERCIAL/PLEASURE
 LOAD DESCRIPTION     : PASSENGERS

*DEPARTED FROM        : SAME AS LOCATION
*INTENDED LANDING AT  : SAME AS LOCATION

 DEPARTURE BRIEFING   : AIS AVAILABLE AND NOT USED
*FLIGHT PLAN/CLEARANCE: NO FLIGHT PLAN - NO CLEARANCE
 TYPE OF FLIGHT PLAN  : NONE
 DURATION OF FLIGHT   : 0 HRS 35 MIN
 AIRSPACE SEGMENT     : UNCONTROLLED AIRSPACE

 PHASE OF OPERATION
* -ONLY PHASE         : APP & LANDING/GO-AROUND

 SPEED AT OCCURRENCE  : 50 KT
 ALTIT. OF OCCURR.    : 21 M (69 FEET)
 SPEED AT IMPACT      : 40 KT

 EMERGENCY CIRCUM.    : OTHER
 MILITARY INVOLVEMENT : NO

<------------------- INJURIES TO PERSONS ----------------------->

*INJURY INDEX         : FATAL

                                  > > > > > NUMBER OF INJURIES < < < < <
 PERSONNEL                FATAL SERIOUS MINOR  NONE UNKNOWN  TOTAL

*PILOT                :          1      .50   .10            1
 TOTAL CREW           :          1                           1

 PASSENGERS           :     1    2                           3

*TOTAL ABOARD         :     1    3                           4

*GRAND TOTAL          :     1    3                           4

<------------------------- DAMAGE ------------------------------>

*DAMAGE TO AIRCRAFT   : SUBSTANTIAL

<--------------- WRECKAGE AND IMPACT INFORMATION --------------->

 WRECKAGE RECOVERED   : YES

 TERRAIN
   -TYPE              : LEVEL FLAT
   -SURFACE-GENERAL   : TREE-COVERED
   -SURFACE-SPECIFIC  : LOOSE

 FIRST IMPACT
   -ELEVATION         : 70 M (230 FEET)
   -IMPACT ANGLE      : 45 DEG

 WRECKAGE TRAIL
   -LENGTH            : 11 M (36 FEET)

 AIRCRAFT ATTITUDE      > > AT IMPACT < <      > > AT REST < <

   -ROLL              : 180 DEG INVERTED     180 DEG INVERTED
   -PITCH             : 180 DEG INVERTED     180 DEG INVERTED
   -YAW               : 45 DEG RIGHT YAW     45 DEG RIGHT YAW

 AERODROME
   -PROXIMITY         : WITHIN .4 KM
   -DIRECTION         : 065 DEG MAGNETIC
```

SURVIVAL DATA

SURVIVABILITY : PARTIALLY SURVIVABLE

POST CRASH ESCAPE : WITH DIFFICULTY

OCCUPANTS
-EVACUATED : 4

IMPACT DAMAGE
-A/C WITH NO CABIN : MODERATE

SEATS
-CONFIGURATION : FORWARD FACING
-OCCUPIED/FAILED : 1

SEAT BELT
-SIGN : NOT INSTALLED

SHOULDER HARNESS
-PILOT : INSTALLED - NOT USED
-COPILOT : INSTALLED - NOT USED

PILOT'S SEAT BELT : FASTENED LOOSELY

EVACUATION
-MEANS OF EXIT : MAIN DOOR, FORWARD
-TIME : OVER 4 MINUTES
-ASSISTANCE : RENDERED EFFECTIVELY

NARRATIVE

THE PILOT WAS ENGAGED IN FLYING FOR AN ORGANIZATION FOR THE PURPOSE OF TAKING ITS MEMBERS ON SHORT SIGHT-SEEING TRIPS.

ON THE FIRST FLIGHT, AFTER ABOUT 15 MINUTES AN APPROACH TO LAND WAS MADE. THE APPROACH SPEED WAS HIGHER THAN NORMAL AND THE PILOT INTENDED TO LAND LONG.

THE AIRCRAFT DRIFTED OFF TO ONE SIDE OF THE NARROW 30 FT WIDE AIRSTRIP. WITH ABOUT 600 FT OF RUNWAY LEFT AND THE AIRCRAFT STILL AIRBORNE THE PILOT APPLIED FULL POWER AND STARTED A CLIMB. FLAPS WERE PARTIALLY RAISED, ALTITUDE WAS LOST AND WITH A POWERLINE IN HIS PATH THE PILOT ATTEMPTED TO CLIMB STEEPLY. THE AIRCRAFT STALLED, STRUCK THE GROUND AND CARTWHEELED.

FACTORS

<A> RELATED TO FIRST OR ONLY TYPE OF OCCURRENCE

01 PILOT:
IMPROPER IN-FLIGHT DECISION OR PLANNING

02 -SPECIFICALLY:
APPROACH POORLY PLANNED

03 MISCELLANEOUS:
EVASIVE MANOEUVRE TO AVOID COLLISION IN FLIGHT

04 MISCELLANEOUS:
INTERFERENCE TO RADIO FACILITIES

05 PILOT:
MISUSED OR FAILED TO USE FLAPS (LIFT DEVICES)

END

Example 3

```
+ ACCIDENT DATA REPORT:  CESSNA - 172                                  FILE 76-C60080 +  PAGE  9
+ TYPE OF OCCURRENCE:  LOSS OF CONTROL IN FLIGHT/MUSH/STRAIGHT STALL                  +  PRINTED
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++31 OCT  89

---------- REPORT IDENTIFICATION ---------->

FROM REGION          : CENTRAL
FILE NUMBER          : C60080
*REPORT SUBMITTED    : 11 FEB 77

LAST RECORD CHANGE   : 11 MAR 83

<---------- OCCURRENCE IDENTIFICATION ----------

*A/C REGISTRATION    : C-GEYY
*STATE OF REGISTRY   : CANADA
*DATE                : 9 JUNE 76
*TIME                : 09:55 LOCAL

LOCATION
* -NAME              : NEAR RICHER
* -PROVINCE          : MANITOBA
* -CATA REGION       : CENTRAL
* -LATITUDE          : 49 39 N
* -LONGITUDE         : 096 24 W
* -STATE/AREA        : CANADA

<---------- HISTORY OF THE FLIGHT ----------

*OPER'N GENERAL AV'N : COMMERCIAL/OTHER
 LOAD DESCRIPTION    : PASSENGERS

*DEPARTED FROM       : WINNIPEG
*INTENDED LANDING AT : WINNIPEG

 DEPARTURE BRIEFING  : AIS AVAILABLE AND USED - INFO VALID
*FLIGHT PLAN/CLEARANCE VFR - NO CLEARANCE
 TYPE OF FLIGHT PLAN : VFR
 DURATION OF FLIGHT  : 1 HRS 55 MIN
 AIRSPACE SEGMENT    : CONTROLLED AIRSPACE

 PHASE OF OPERATION
* -ONLY PHASE        : ENROUTE/UNAUTHORIZED LOW FLYING

 SPEED AT OCCURRENCE : 55 KT
 ALTIT. OF OCCURR.   : 366 M (1201 FEET)
 SPEED AT IMPACT     : 50 KT

 MILITARY INVOLVEMENT: NO

<---------- INJURIES TO PERSONS ----------

*INJURY INDEX        : FATAL

                          > > > > > NUMBER OF INJURIES < < < < <
 PERSONNEL            FATAL SERIOUS MINOR  NONE UNKNOWN  TOTAL
*PILOT          :       1      -50  -25                     1
 TOTAL CREW     :       1                                   1

 PASSENGERS     :              2                            2

*TOTAL ABOARD   :       1      2                            3

*GRAND TOTAL    :       1      2                            3

<---------- DAMAGE ----------

*DAMAGE TO AIRCRAFT  : DESTROYED

<---------- WRECKAGE AND IMPACT INFORMATION ----------

 WRECKAGE RECOVERED  : YES

 TERRAIN
  -TYPE              : LEVEL FLAT
  -SURFACE-GENERAL   : TREE-COVERED
  -SURFACE-SPECIFIC  : LOW VEGETATION/GRASS

 FIRST IMPACT
  -ELEVATION         : 311 M (1020 FEET)
  -IMPACT ANGLE      : 40 DEG

 AIRCRAFT ATTITUDE      > > AT IMPACT < <      > > AT REST < <
  -ROLL             : 30 DEG LEFT ROLL        0 DEG WINGS LEVEL
  -PITCH            : 30 DEG NOSE DOWN        30 DEG NOSE DOWN
  -YAW              : 0 DEG ZERO YAW          0 DEG ZERO YAW

<---------- SURVIVAL DATA ----------

 SURVIVABILITY       : PARTIALLY SURVIVABLE

 POST CRASH ESCAPE   : WITH DIFFICULTY

 IMPACT DAMAGE
  -A/C WITH NO CABIN : SEVERE

 SEATS
  -CONFIGURATION     : FORWARD FACING
```

SURVIVAL DATA (CONTINUED)

SEAT BELT
-SIGN : NOT INSTALLED

SHOULDER HARNESS
-PILOT : INSTALLED - NOT USED
-COPILOT : INSTALLED - NOT USED

PILOT'S SEAT BELT : FASTENED LOOSELY

EVACUATION
-MEANS OF EXIT : MAIN DOOR, FORWARD
-TIME : 31 - 60 SECONDS
-ASSISTANCE : RENDERED EFFECTIVELY
-CHUTE/SLIDE : NOT AVAILABLE
-LADDER : NOT AVAILABLE
-EMERGENCY EXITS : WOULD NOT OPEN (ONE OR MORE)
-EMERGENCY LIGHTS : NOT AVAILABLE

NARRATIVE

THE AIRCRAFT WAS CHARTERED FOR THE PURPOSE OF TRAINING RCMP OFFICERS IN AERIAL TRAFFIC OBSERVATION AND ENFORCEMENT PROCEDURES. THE EXERCISE CONSISTED OF OBSERVING TWO VEHICLES, ONE ACTING AS A HIGHWAY VIOLATION SUSPECT AND THE OTHER AS A PATROL INTERCEPT CAR. THE AIRCRAFT WAS USED TO DETERMINE VIOLATION VEHICLE SPEED AND RADIO INFORMATION TO THE PATROL CAR. THE VIOLATION VEHICLE TRAVELLING EAST ON THE TRANS CANADA HIGHWAY MADE A RIGHT TURN ONTO A SECONDARY ROAD AND AFTER APPROXIMATELY 1/2 MILE STOPPED, BACKED UP A FEW YARDS AND AND TURNED LEFT INTO A FIELD. THE AIRCRAFT FOLLOWED THE VIOLATIO VEHICLE, DESCENDED AND COMMENCED A LEFT TURN. THE AIRCRAFT WAS MAINTAINING SLOW FLIGHT WITH PARTIAL FLAP EXTENDED AND DURING THE TURN IT STALLED AND STRUCK THE GROUND APPROXIMATELY 100 FEET FROM THE VIOLATION VEHICLE. THE RCMP OFFICERS FROM THE VEHICLE WERE ABLE TO CONTAIN THE BLAZE OF THE POST CRASH FIRE AND RESCUE THE THREE OCCUPANTS FROM THE AIRCRAFT. IT APPEARS THE ATTENTION OF THE PILOT WAS DIVERTED FROM HIS PRIMARY DUTY AT A CRITICAL PHASE OF THE FLIGHT. IN ADDITION, THE FINAL TURN WAS MADE DOWNWIND AND AT LOW LEVEL, EXPOSING HIM TO THE ILLUSION OF HIGHER SPEED DUE TO MISLEADING VISUAL CUES. WHILE THUS DISTRACTED, THE PILOT PERMITTED THE AIRCRAFT TO STALL.

FACTORS

<A> RELATED TO FIRST OR ONLY TYPE OF OCCURRENCE

01 PILOT:
FAILED TO OBTAIN/MAINTAIN FLYING SPEED

02 PILOT:
DIVERTED ATTENTION FROM OPERATION OF A/C

03 MISCELLANEOUS:
SEE WRITTEN FACTOR

WRITTEN FACTORS

TURN DOWNWIND - POSSIBLE ILLUSION DUE TO DRIFT

END

Example 4

```
+ ACCIDENT DATA REPORT:  CESSNA - 172                          FILE 77-Q70033 +  PAGE  11
+ TYPE OF OCCURRENCE:    LOSS OF CONTROL IN FLIGHT/SPIRAL                     +  PRINTED
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++31 OCT  89

<---------- REPORT IDENTIFICATION ---------->

*FROM REGION          : QUEBEC
*FILE NUMBER          : Q70033
*REPORT SUBMITTED     : 10 FEB 78

 LAST RECORD CHANGE   : 10 NOV 83

<---------- OCCURRENCE IDENTIFICATION ---------->

*A/C REGISTRATION     : CF-ZXY
*STATE OF REGISTRY    : CANADA
*DATE                 : 24 APR 77
*TIME                 : 15:15 LOCAL

 LOCATION
* -NAME               : LAC FIEDMONT
* -PROVINCE           : QUEBEC
* -CATA REGION        : QUEBEC
* -LATITUDE           : 48 19 N
* -LONGITUDE          : 073 41 W
* -STATE/AREA         : CANADA

<---------- HISTORY OF THE FLIGHT ---------->

*OPER'N GENERAL AV'N  : NONCOMMERCIAL/PLEASURE
 LOAD DESCRIPTION     : PASSENGERS

*DEPARTED FROM        :  VAL D'OR
*INTENDED LANDING AT  :  VAL D'OR

 DEPARTURE BRIEFING   : AIS AVAILABLE AND NOT USED
*FLIGHT PLAN/CLEARANCE OTHER
 TYPE OF FLIGHT PLAN  : NONE
 DURATION OF FLIGHT   : 0 HRS 20 MIN
 AIRSPACE SEGMENT     : UNCONTROLLED AIRSPACE

 PHASE OF OPERATION
* -ONLY PHASE         : ENROUTE/UNAUTHORIZED LOW FLYING

 SPEED AT OCCURRENCE  : 100 KT
 ALTIT. OF OCCURR.    : 15 M (49 FEET)
 SPEED AT IMPACT      : 110 KT

 EMERGENCY CIRCUM.    : ADVERSE WEATHER
 MILITARY INVOLVEMENT: NO

<---------- INJURIES TO PERSONS ---------->

*INJURY INDEX         : FATAL

                                > > > > > NUMBER OF INJURIES < < < < <
 PERSONNEL                FATAL SERIOUS MINOR  NONE UNKNOWN  TOTAL

*PILOT                :    1      30     0                      1
 TOTAL CREW           :    1                                    1

 PASSENGERS           :    2       1                           3

*TOTAL ABOARD         :    3       1                           4

*GRAND TOTAL          :    3       1                           4

<---------- DAMAGE ---------->

*DAMAGE TO AIRCRAFT   : DESTROYED

<---------- WRECKAGE AND IMPACT INFORMATION ---------->

 WRECKAGE RECOVERED   : YES

 TERRAIN
  -TYPE               : MOUNTAINOUS
  -SURFACE-GENERAL    : TREE-COVERED

 FIRST IMPACT
  -ELEVATION          : 351 M (1152 FEET)
  -IMPACT ANGLE       : 20 DEG

 WRECKAGE TRAIL
  -LENGTH             : 55 M (180 FEET)

 AIRCRAFT ATTITUDE     > > AT IMPACT < <      > > AT REST < <

  -ROLL               : 90 DEG LEFT ROLL     120 DEG LEFT ROLL
  -PITCH              : 30 DEG NOSE DOWN     180 DEG INVERTED
  -YAW                : 0 DEG ZERO YAW       90 DEG RIGHT YAW

 AERODROME
  -PROXIMITY          : BEYOND 8 KM
  -DIRECTION          : 360 DEG MAGNETIC
```

+ ACCIDENT DATA REPORT: CESSNA - 172 FILE 77-Q70033 +
+ TYPE OF OCCURRENCE: LOSS OF CONTROL IN FLIGHT/SPIRAL +

<---------- SURVIVAL DATA ---------->

SURVIVABILITY : PARTIALLY SURVIVABLE

POST CRASH ESCAPE : WITH DIFFICULTY

OCCUPANTS
-EVACUATED : 1
-NOT EVACUATED : 3

IMPACT DAMAGE
-COCKPIT : EXTREME
-FORWARD CABIN : SEVERE
-CENTRE CABIN : SEVERE
-AFT CABIN : MODERATE

SEATS
-CONFIGURATION : FORWARD FACING

SEAT BELT
-SIGN : NOT INSTALLED

SHOULDER HARNESS
-PILOT : NOT INSTALLED
-COPILOT : NOT INSTALLED

PILOT'S SEAT BELT : FAILED

EVACUATION
-MEANS OF EXIT : MAIN DOOR, FORWARD
-TIME : OVER 5 MINUTES
-ASSISTANCE : RENDERED EFFECTIVELY

<---------- NARRATIVE ---------->

THE AIRCRAFT STRUCK A TREE THEN CRASHED INTO THE GROUND AT HIGH SPEED UNDER POWER SOME 180 FEET FURTHER ON, AND SLID ANOTHER 25 FEET BEFORE COMING TO REST. THERE IS CONJECTURE THAT THE PILOT WAS LOW FLYING, BUT THE ACTUAL CAUSE OF THE CRASH IS UNDETERMINED.

<---------- FACTORS ---------->

<A> RELATED TO FIRST OR ONLY TYPE OF OCCURRENCE

01 MISCELLANEOUS:
UNDETERMINED

APPENDIX E

DBASE COMPUTER PROGRAM FOR CALCULATING COST BENEFIT-RATIOS

```
* Cost-Benefit Analysis of Retrofit Shoulder Harness
* Installation For Small Commercial Aeroplanes
*
SET ECHO OFF
SET TALK OFF
SET ALTERNATE TO SHCBMM.RES
*Use Small comm. Aeroplane CARS database sorted by year built
USE CARSSA
* Values of death and injury
DF=2500000
DS=660000
DM=3000
* Default retrofit cost
DEFCOST=2000
* Expected savings due to shoulder harness installation and
use
ESINST=(0.142-0.102)*DF+(0.091-0.067)*DS+(0.086-0.097)*DM
*ESINST=(0.142-0.135)*DF+(0.091-0.034)*DS+(0.086-0.097)*DM
ESUSED=(0.142-0.077)*DF+(0.091-0.042)*DS+(0.086-0.083)*DM
*ESUSED=(0.142-0.118)*DF+(0.091-0.001)*DS+(0.086-0.083)*DM
* Occupancy rate of co-pilots seat
IF NO_SEATS>1
  COPOCC=0.60
ELSE
  COPOCC=0.0
ENDIF
ESINST=ESINST*(1+COPOCC)
ESUSED=ESUSED*(1+COPOCC)
TB10INST=0
TB5INST=0
TB10USED=0
TB5USED=0
TOTCOST=0
NO78=0
NOB78=0
NOUNKN=0
YRBP=-1
SPRACC=0
NOACCS=0
DO WHILE .NOT. EOF()
* Skip aircraft which already have shoulder harnesses
installed
IF (YRBUILT>78 .AND. COUNTRYMAN='3') .OR. SH_COST=-1
  SKIP
  LOOP
ENDIF
* Sum accident savings until a/c is 40 years old
  YRB=YRBUILT
  IF YRBUILT=0
    YRB=68
    NOUNKN=NOUNKN+1
  ENDIF
```

```
IF YRB<51
  YRB=51
ENDIF
IF SH_COST=0
  RETFIT=DEFCOST
ELSE
  RETFIT=SH_COST
ENDIF
IF YRBUILT<>YRBP
 YR=89
 T10INST=0
 T5INST=0
 T10USED=0
 T5USED=0
 D5FAC=1.0
 D10FAC=1.0
 PRACC=0
 SPRACC=0
 DO WHILE YR<=YRB+40
  PRACC=(1-SPRACC)*0.00009*(464-5.8*(YR-YRB))
*  PRACC=(1-SPRACC)*0.00009*348
  SPRACC=SPRACC+PRACC
  XX=ESINST*PRACC*D10FAC
  T10INST=T10INST+XX
  T5INST=T5INST+ESINST*PRACC*D5FAC
  T10USED=T10USED+ESUSED*PRACC*D10FAC
  T5USED=T5USED+ESUSED*PRACC*D5FAC
  YR=YR+1
  D10FAC=D10FAC/(1.10)
  D5FAC=D5FAC/(1.05)
 ENDDO
 YRBP=YRBUILT
ENDIF
* Factor costs and benefits to allow for a/c with shoulder
* harness installed after manufacture
IF YRB=78
 FAC=0.5*0.60
 NO78=NO78+1
ENDIF
IF YRB<>78
 FAC=0.60
 NOB78=NOB78+1
ENDIF
* Sum accident savings and retrofit costs over all aircraft
NOACCS=NOACCS+SPRACC
TB10INST=TB10INST+T10INST*FAC/1000000
TB5INST=TB5INST+T5INST*FAC/1000000
TB10USED=TB10USED+T10USED*FAC/1000000
TB5USED=TB5USED+T5USED*FAC/1000000
TOTCOST=TOTCOST+0.65*RETFIT/1000000
RATIO=T10INST/RETFIT
REPLACE CBRATIO WITH RATIO
```

```
?TYPE,YRB,STR(RETFIT,8,0),STR(T10INST,8,0),STR(RATIO,8,2),
STR(SPRACC,6,4)
  SKIP
ENDDO
NOB78=NOB78+NO78/2
* Calculate cost benefit ratios
R10USED=TB10USED/TOTCOST
R5USED=TB5USED/TOTCOST
R10INST=TB10INST/TOTCOST
R5INST=TB5INST/TOTCOST
SET ALTERNATE ON
?
?'Average savings of shoulder harness in an accident given:'
?'                              100% usage $',STR(ESUSED,7,0)
?'                           current usage $',STR(ESINST,7,0)
?
?'No. of aircraft not required to have SHs ',STR(NOB78,5,0)
?'No. of aircraft manufactured during 1978 ',STR(NO78,5,0)
?'                                 unknown     ',STR(NOUNKN,5,0)
?'-------------------------------------------------------------
--'
?'Retrofit            Accident Savings & Cost Benefit Ratio'
?'Cost             With 100% Usage            With Current Usage'
?'million     5% DRate      10% DRate     5% DRate     10%
DRate'
?'            $ million     $million      $million
$million '
?'-------------------------------------------------------------
--'
? STR(TOTCOST,6,2),STR(TB5USED,12,2),STR(TB10USED,13,2),
STR(TB5INST,13,2),STR(TB10INST,13,2)
?'   ',STR(R5USED,12,2),STR(R10USED,13,2),STR(R5INST,13,2),
STR(R10INST,13,2)
?'-------------------------------------------------------------
--'
?'Values used in analysis: life saved       $',STR(DF,8,0)
?'                         serious injury   $',STR(DS,8,0)
?'                         minor injury     $',STR(DM,8,0)
?'Occupancy rate of co-pilots seat          =',STR(COPOCC,8,3)
?'Default cost of shoulder harness retrofit
$',STR(DEFCOST,6,0)
?'Number of accidents for current aircraft =',STR(NOACCS,8,1)
SET ALTERNATE OFF
CLOSE ALTERNATE
RETURN
```

RESULTS OF COST-BENEFIT ANALYSIS FOR SMALL COMMERCIAL AEROPLANES

Average savings of shoulder harness in an accident given:

100% usage	$ 311758
current usage	$ 185291

No. of aircraft not required to have SHs	3024
No. of aircraft manufactured during 1978	215
unknown	67

Retrofit Cost million	Accident Savings & Cost Benefit Ratio With 100% Usage		With Current Usage	
	5% DRate $ million	10% DRate $million	5% DRate $million	10% DRate $million
3.33	170.28	128.34	101.20	76.28
	51.08	38.50	30.36	22.88

Values used in analysis: life saved	$	2500000
serious injury	$	660000
minor injury	$	3000
Occupancy rate of co-pilots seat	=	0.600
Default cost of shoulder harness retrofit	$	2000
Number of accidents for current aircraft	=	1299.5